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JULY 1946

Monthly
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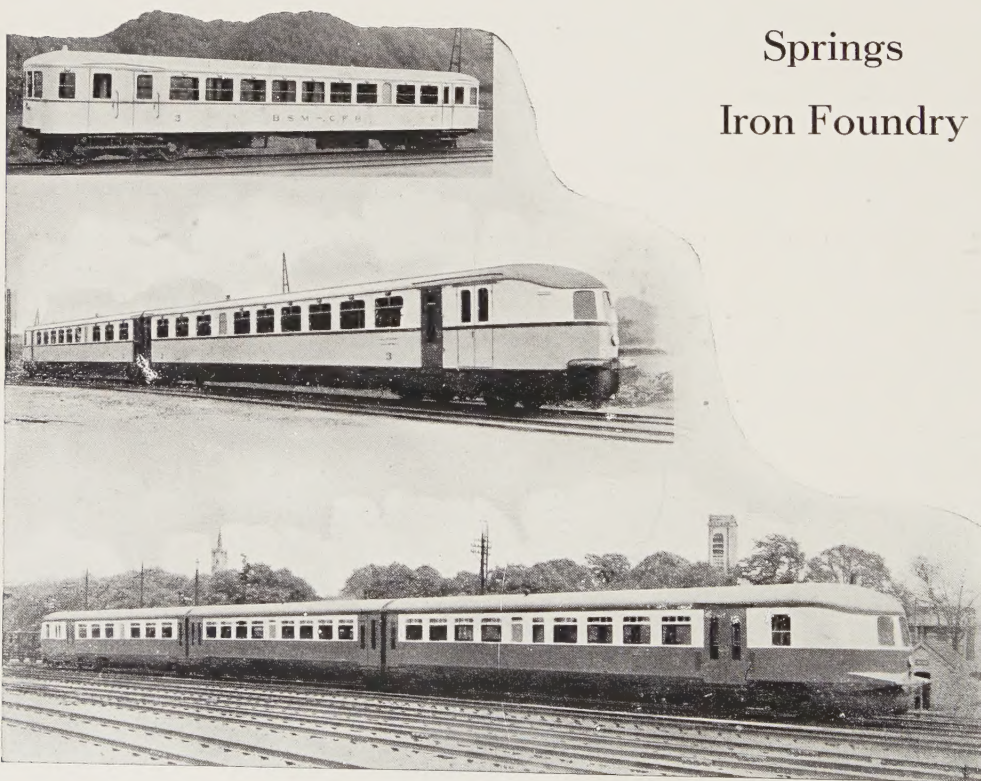
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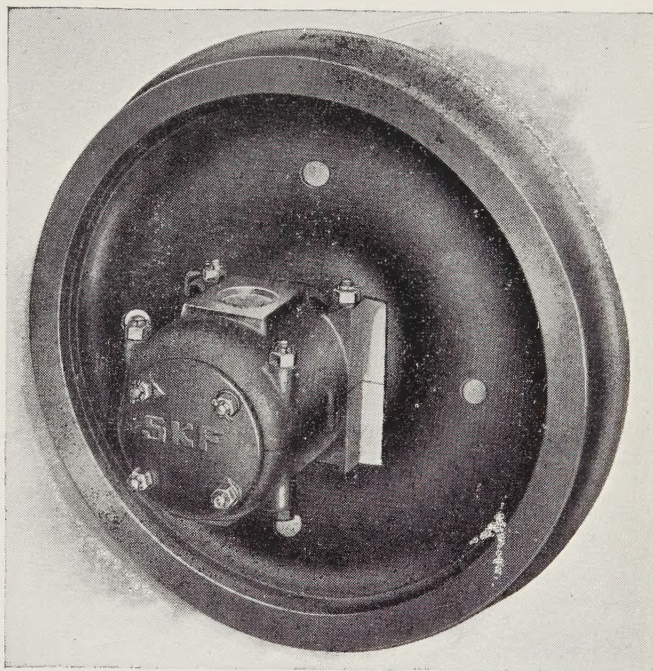
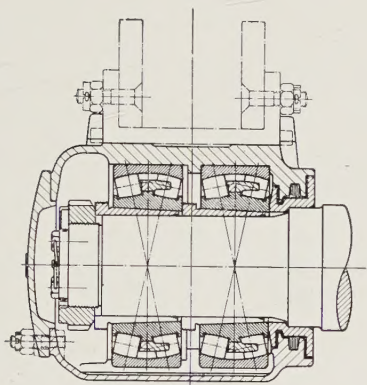
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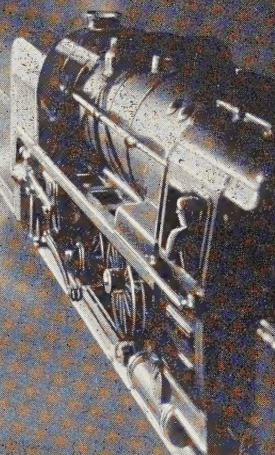
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OF THE

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(ENGLISH EDITION)

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BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS

ASSOCIATION

(ENGLISH EDITION)

[625. 251]

Contribution to the study of braking of railcars and autotrains with the object of calculating stopping distances,

by M. EDGAR HENNIG, I.C.M., A.I.Br.,

Engineer (Rolling Stock Department of the Belgian National Railways).

The object of this treatise is to make a contribution to research into methods of calculating the distances required to pull up railcars, autotrains, etc.

In this treatise, the influence of wind resistance has been taken specially into account.

The first part deals with the question in a general way. The second part considers in particular the period during which the brake cylinders are put into operation. Lastly, the third part relates to the uncertain transitory period between pure rolling and pure skidding following the application of the brakes to the wheels.

* * *

Let us recall, first of all, that the factors to be considered in the braking of a vehicle (*) are the following :

1) The total weight of the vehicle = P tonnes.

(*) The term « vehicle » used in this treatise will be taken to represent a railcar or autotrains, etc.

2) The aerodynamic coefficient of the vehicle.

3) The total effort required in applying the brake shoes to the tyres = Q tonnes.

4) The radius of the wheels = r metres.

5) The mass moment of inertia of the trains of wheels, including the rotating masses coupled to them = $I \text{ kgr.} \times \text{m.} \times \text{sec}^2$.

* * *

The following notations will be used :

1) $K = \frac{Q}{P} = \frac{Q}{P_0 + P_1}$ = the coefficient of brake power, P_0 being the tare, and P_1 tonnes the weight of the freight.

2) $M = \frac{1000 P}{g}$ = the total mass of the vehicle, including that of the trains of wheels, g being the acceleration due to gravity, expressed in metres per second per second.

3) t = the time, in seconds.

4) V = the instantaneous velocity of the vehicle, in kilometres per hour.

5) v = the same velocity, in metres per second, so that

$$v = \frac{V}{3.6} \text{ and } V = 3.6 v.$$

6) ω = the angular velocity of the wheels, in radians per second.

7) α = the specific resistance of rolling of the vehicle, in kilogrammes per tonne of weight transmitted by the vehicle to the rails.

8) S = the largest frontal section of the vehicle in square metres.

9) β = the aerodynamic coefficient of the vehicle, the overall wind resistance of the vehicle which is equal to $\beta \times S \times v^2$ where v is expressed in metres per second.

10) i = the gradient of the line, in millimetres per metre (+ i for inclines and $-i$ for declines).

11) f = the coefficient of friction between the cast shoes and the steel tyres of the wheels.

12) f' = the coefficient of friction in the case of pure skidding between the steel tyres and the steel rails, the wheels being locked.

13) δ = the value of the total retarding effort, in kilogrammes.

* * *

With regard to the coefficient of friction $f = \Phi(v)$, it is known that, since the time, already distant, when Douglas GALTON and WESTINGHOUSE conducted their well-known classical experiments without ever exceeding the speed of 90 km./h., other experimenters have proposed the use of coefficients established for speeds varying between wider limits.

It seems, according to these experimenters, that the function $f = \Phi(v)$ can be given in the form

$$(v + A)(f - B) = C$$

which defines a rectangular hyperbola tending to asymptotes which are parallel with the co-ordinate axes, so that

$$f = B + \frac{C}{v + A}$$

$$= \frac{Bv + AB + C}{v + A}$$

$$= \frac{Bv + D}{v + A}$$

$$= \frac{D}{A} \times \frac{\frac{B}{D}v + 1}{\frac{v}{A} + 1}$$

or, substituting $\frac{D}{A} = a$, $\frac{B}{D} = b$ and $\frac{1}{A} = c$:

$$f = a \times \frac{bv + 1}{cv + 1}$$

For instance, WICHERT puts forward:

$$\left. \begin{aligned} \text{— Dry rails: } f &= 0.45 \times \frac{0.0112V + 1}{0.06V + 1} \\ \text{— Damp rails: } f &= 0.25 \times \frac{0.0112V + 1}{0.06V + 1} \end{aligned} \right\} V \text{ in km./h.}$$

In the calculations which follow, we shall always keep to the linear formula $f = a - bv$ relating to a chord of the hyperbola in so far as the said chord may be carefully chosen in order to produce a sufficiently near result (*).

Moreover, we shall neglect any influence on the value of the coefficient f of :

- 1) The rate of the *specific* pressure exerted by the brake shoes on the tyres of the wheels.
- 2) The *duration* of this pressure.

PART I.

General examination of the problem of determining stopping distances.

Generally, the problem of calculating stopping distances can be stated thus :

Given a speed (v_1), as well as the characteristics of the vehicle and the gradient (i) of the line :

1) Calculate the time (t) taken to decelerate to a given speed (v_2), also the distance travelled (l_1) to reach this speed;

2) Calculate the speed (v_2) reached after travelling a given distance (l_1), also the time (t_1) taken to travel that distance;

3) Calculate the speed (v_2) reached after a given time (t_1), also the distance travelled (l_1) during this time.

Moreover three hypotheses have to be considered :

I. Auto-variable braking (pure rolling).

II. Constant-pressure braking (pure rolling).

III. Pure skidding (wheels braked).

* * *

Bearing in mind the notations adopted, the differential equation for the movement of a braked vehicle can be written :

$$M \frac{dv}{dt} + \frac{I}{r} \frac{d\omega}{dt} = -\delta$$

or :

$$\left(M + \frac{I}{r^2} \right) \frac{dv}{dt} = -\delta$$

Now, the equation with respect to dimensions :

$$\frac{I}{r^2} = \frac{\text{Kgr.} \times \text{m.} \times \text{sec}^2}{\text{m}^2} = \frac{\text{Kgr}}{\frac{\text{m.}}{\text{sec}^2}} = \text{mass}$$

can be written :

$$\frac{I}{r^2} = \text{mass } M'.$$

Under these conditions, the equation for movement can be given in the form :

$$(M + M') \frac{dv}{dt} = -\delta$$

or :

$$M \left(1 + \frac{M'}{M} \right) \frac{dv}{dt} = -\delta$$

(*) *Example :*

Dry rails	{	$f = 0.40 - 0.022 v$		for $v < 10$ m./sec.
		$f = 0.20 - 0.002 v$		for $v > 10$ m./sec.
Damp rails	{	$f = 0.22 - 0.011 v$		for $v < 10$ m./sec.
		$f = 0.124 - 0.0014 v$		for $v > 10$ m./sec.

or, in stating :

$$1 + \frac{M'}{M} = \eta$$

$$M\eta \frac{dv}{dt} = -\delta$$

or

$$\begin{aligned} \frac{dv}{dt} &= -\frac{\delta}{M\eta} \\ &= -\frac{g\delta}{1000 P\eta} \end{aligned}$$

from which :

$$dt = -\frac{1000 P\eta}{g} \times \frac{dv}{\delta} \dots \dots (I)$$

and, it follows :

$$\begin{aligned} dl &= vdt \\ &= -\frac{1000 P\eta}{g} \times \frac{v dv}{\delta} \dots \dots (II) \end{aligned}$$

I. Autovvariable Pressure Brake.

It can be accepted that during the period of automatic variation of pressure in the brake cylinders (from the speed v_A characterizing the origin of the period to the speed zero) the effort to be applied to the brake blocks will vary according to the decreasing speed of the vehicle, i.e. following a *linear* law.

Hence, if :

$Q_1 = KP$ = the effort applied to the brake blocks at the beginning of the period of autovariability;

Q = the effort to be automatically applied to the blocks corresponding to an intermediate velocity v between the velocities v_A and zero;

k = the angular coefficient from the straight line following the linear law of variation of the autovvariable effort Q in relation to the decreasing speed (v);

we can write :

$$\begin{aligned} Q &= Q_1 - k(v_A - v) \\ &= KP - kv_A + kv \end{aligned}$$

or, substituting

$$\begin{aligned} kv_A &= k' : \\ Q &= KP - k' + kv \end{aligned}$$

Under these conditions, if $f = a - bv$ follows the linear law chosen for the variation of the coefficient of friction « shoe on tyre » in relation to the circumferential velocity of the wheels, the decelerating force δ will have an instantaneous value during the period of brake application :

$$\begin{aligned} \delta &= 1000 fQ + \alpha P + \beta S v^2 \pm iP \\ &= 1000 (a - bv) (KP - k' + kv) \\ &\quad + \alpha P + \beta S v^2 \pm iP \\ &= (\beta S - 1000 kb) \left\{ v^2 \right. \\ &\quad \left. + \frac{1000 (ka - KPb + k'b)}{\beta S - 1000 kb} \right\} \\ &\quad + \frac{1000 (KP - k') a + \alpha P \pm iP}{\beta S - 1000 kb} \left\{ \right. \\ &= (\beta S - 1000 kb) (v^2 + pv + q) \end{aligned}$$

a value which, when substituted in the differential equations I and II, allows them to be written in the form :

$$\left\{ \begin{aligned} dt &= -\frac{1000 P\eta}{g (\beta S - 1000 kb)} \\ &\quad \times \frac{dv}{v^2 + pv + q} \\ dl &= -\frac{1000 P\eta}{g (\beta S - 1000 kb)} \\ &\quad \times \frac{v dv}{v^2 + pv + q} \end{aligned} \right.$$

or

$$\left\{ \begin{aligned} dt &= -\gamma \times \frac{dv}{v^2 + pv + q} \\ dl &= -\gamma \times \frac{v dv}{v^2 + pv + q} \end{aligned} \right.$$

so that :

$$\left\{ \begin{array}{l} t = -\gamma \int \frac{dv}{v^2 + pv + q} \end{array} \right. \quad (III)$$

$$\left\{ \begin{array}{l} l = -\gamma \int \frac{v dv}{v^2 + pv + q} \end{array} \right. \quad (IV)$$

expressions in which :

$$\left\{ \begin{array}{l} \gamma = \frac{1000 P \gamma_1}{g (\beta S - 1000 kb)} \\ p = \frac{1000 (ka - Kpb + k'b)}{\beta S - 1000 kb} \\ q = \frac{1000 (KP - k') a + \alpha P \pm iP}{\beta S - 1000 kb} \end{array} \right.$$

II. Constant Pressure Brake.

As here $k = 0$ and $k' = 0$, the parameters γ , p , q in the equations (III) and (IV) become :

$$\begin{aligned} \gamma &= \frac{1000 P \gamma_1}{g \beta S} \\ p &= - \frac{1000 K b P}{\beta S} \\ q &= \frac{(1000 K a + \alpha \pm i) P}{\beta S} \end{aligned}$$

III. Skidding with Locked Wheels.

Bearing in mind that :

1) The law $f' = a' - b'v$ must be substituted here for $f = a - bv$;

2) $K = 1$, since here the skidding friction Pf' of the tyres on the rail takes the place of the friction KPf of the brake blocks on the tyres;

3) $a = 0$, seeing that rolling resistance is no longer present;

4) $\gamma_1 = 1$, as wheels are no longer rotating;

the parameters γ , p , q , in the equations (III) and (IV) become :

$$\begin{aligned} \gamma &= \frac{1000 P}{g \beta S} \\ p &= - \frac{1000 b' P}{\beta S} \\ q &= \frac{(1000 a' \pm i) P}{\beta S} \end{aligned}$$

Resolution of the integrals (III) and (IV) common to the three forms of braking considered.

1st case : $\frac{p^2}{4} - q > 0$.

We find :

$$\begin{aligned} \int \frac{dv}{v^2 + pv + q} &= - \frac{1}{2 \sqrt{\frac{p^2}{4} - q}} \log_n \frac{\left(\sqrt{\frac{p^2}{4} - q} + \frac{p}{2} \right) + v}{\left(\sqrt{\frac{p^2}{4} - q} - \frac{p}{2} \right) - v} \\ \int \frac{v dv}{v^2 + pv + q} &= \frac{\sqrt{\frac{p^2}{4} - q} + \frac{p}{2}}{2 \sqrt{\frac{p^2}{4} - q}} \int \frac{dv}{v + \left(\sqrt{\frac{p^2}{4} - q} + \frac{p}{2} \right)} \\ &\quad + \frac{\sqrt{\frac{p^2}{4} - q} - \frac{p}{2}}{2 \sqrt{\frac{p^2}{4} - q}} \int \frac{dv}{v - \left(\sqrt{\frac{p^2}{4} - q} - \frac{p}{2} \right)} \end{aligned}$$

or, writing :

$$\sqrt{\frac{p^2}{4} - q} = \Delta$$

$$\sqrt{\frac{p^2}{4} - q} + \frac{p}{2} = \Delta + \frac{p}{2} = -A, \text{ so that } A = -\left(\Delta + \frac{p}{2}\right)$$

$$\sqrt{\frac{p^2}{4} - q} - \frac{p}{2} = \Delta - \frac{p}{2} = B$$

and integrating between the limits of speed v_1 and v_2 :

$$\begin{aligned} \int_{v_1}^{v_2} \frac{dv}{v^2 + pv + q} &= -\frac{1}{2\Delta} \left\{ \log_n \frac{-A + v}{B - v} \right\}_{v_1}^{v_2} \\ &= -\frac{1}{2\Delta} \left\{ \log_n \frac{-A + v_2}{B - v_2} - \log_n \frac{-A + v_1}{B - v_1} \right\} \\ &= -\frac{1}{2\Delta} \left\{ \log_n (-A + v_2) - \log_n (B - v_2) \right. \\ &\quad \left. - \log_n (-A + v_1) + \log_n (B - v_1) \right\} \\ &= -\frac{1}{2\Delta} \left\{ \log_n \frac{-A + v_2}{-A + v_1} + \log_n \frac{B - v_1}{B - v_2} \right\} \\ &= -\frac{1}{2\Delta} \left\{ \log_n \frac{A - v_2}{A - v_1} - \log_n \frac{B - v_2}{B - v_1} \right\} \end{aligned}$$

$$\begin{aligned} \int_{v_1}^{v_2} \frac{v dv}{v^2 + pv + q} &= -\frac{A}{2\Delta} \int_{v_1}^{v_2} \frac{dv}{v - A} + \frac{B}{2\Delta} \int_{v_1}^{v_2} \frac{dv}{v - B} \\ &= \frac{1}{2\Delta} \left\{ -A \log_n \frac{v_2 - A}{v_1 - A} + B \log_n \frac{v_2 - B}{v_1 - B} \right\} \\ &= \frac{1}{2\Delta} \left\{ -A \log_n \frac{A - v_2}{A - v_1} + B \log_n \frac{B - v_2}{B - v_1} \right\} \end{aligned}$$

1) If values of v_1 and v_2 are given :

$$t_1 = -\gamma \int_{v_1}^{v_2} \frac{dv}{v^2 + pv + q} = -\gamma \left[-\frac{1}{2\Delta} \left\{ \log_n \frac{A - v_2}{A - v_1} - \log_n \frac{B - v_2}{B - v_1} \right\} \right]$$

$$= \frac{\gamma}{2\Delta} \left\{ \log_n \frac{A - v_2}{A - v_1} - \log_n \frac{B - v_2}{B - v_1} \right\} \cdot \cdot \cdot \cdot \cdot \quad (1)$$

$$\text{or, if } v_2 = 0 : \quad t_1 = \frac{\gamma}{2\Delta} \left\{ \log_n \frac{A}{A - v_1} - \log_n \frac{B}{B - v_1} \right\} \cdot \cdot \cdot \cdot \cdot \quad (1')$$

$$l_1 = - \gamma \int_{v_1}^{v_2} \frac{v dv}{v^2 + pv + q} = - \gamma \left[\frac{1}{2\Delta} \left\{ A \log_n \frac{A - v_2}{A - v_1} + B \log_n \frac{B - v_2}{B - v_1} \right\} \right]$$

$$= \frac{\gamma}{2\Delta} \left\{ A \log_n \frac{A - v_2}{A - v_1} - B \log_n \frac{B - v_2}{B - v_1} \right\} \cdot \cdot \cdot \cdot \quad (2)$$

$$\text{or, if } v_2 = 0 : \quad l_1 = \frac{\gamma}{2\Delta} \left\{ A \log_n \frac{A}{A - v_1} - B \log_n \frac{B}{B - v_1} \right\} \cdot \cdot \cdot \cdot \quad (2')$$

2) If values of v_1 and l_1 are given :

The value of v_2 is obtained from equation (2) expressed thus :

$$l_1 = \frac{\gamma}{2\Delta} \left\{ A \log_n (A - v_2) - A \log_n (A - v_1) - B \log_n (B - v_2) + B \log_n (B - v_1) \right\}$$

or, substituting :

$$B \log_n (B - v_1) - A \log_n (A - v_1) = \varepsilon$$

$$l_1 = \frac{\gamma}{2\Delta} \left\{ A \log_n (A - v_2) - B \log_n (B - v_2) + \varepsilon \right\}$$

from which it follows :

$$A \log_n (A - v_2) - B \log_n (B - v_2) = \frac{2\Delta l_1}{\gamma} - \varepsilon \cdot \cdot \cdot \cdot \quad (3)$$

a transcendent equation from which the value of v_2 must be obtained by calculation.

3) If values of v_1 and t_1 are given :

v_2 is obtained from equation (1) written thus :

$$\log_n \frac{(A - v_2) (B - v_1)}{(B - v_2) (A - v_1)} = \frac{2\Delta t_1}{\gamma}$$

from which

$$\frac{(A - v_2) (B - v_1)}{(B - v_2) (A - v_1)} = e^{\frac{2\Delta t_1}{\gamma}}$$

and consequently :

$$\frac{A - v_2}{B - v_2} = \frac{A - v_1}{B - v_1} \cdot e^{\frac{2\Delta t_1}{\gamma}}$$

$$\begin{aligned}
 &= \frac{1}{2} \log_n \frac{\left(v_2 + \frac{p}{2}\right)^2 + \Theta^2}{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2} + \frac{p}{2\Theta} \left[\operatorname{arc} \operatorname{tg} \frac{v_1 + \frac{p}{2}}{\Theta} - \operatorname{arc} \operatorname{tg} \frac{v_2 + \frac{p}{2}}{\Theta} \right] \\
 &= \frac{1}{2} \log_n \frac{\left(v_2 + \frac{p}{2}\right)^2 + \Theta^2}{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2} + \frac{p}{2\Theta} \operatorname{arc} \operatorname{tg} \frac{\Theta (v_1 - v_2)}{\Theta^2 + \left(v_1 + \frac{p}{2}\right) \left(v_2 + \frac{p}{2}\right)} \\
 &= -\frac{1}{2} \log_n \frac{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2}{\left(v_2 + \frac{p}{2}\right)^2 + \Theta^2} + \frac{p}{2\Theta} \operatorname{arc} \operatorname{tg} \frac{\Theta (v_1 - v_2)}{\Theta^2 + \left(v_1 + \frac{p}{2}\right) \left(v_2 + \frac{p}{2}\right)}
 \end{aligned}$$

1) If values of v_1 and v_2 are given, we have :

$$\begin{aligned}
 t_1 &= -\gamma \int_{v_1}^{v_2} \frac{dv}{v^2 + pv + q} = -\gamma \left\{ -\frac{1}{\Theta} \operatorname{arc} \operatorname{tg} \frac{\Theta (v_1 - v_2)}{\Theta^2 + \left(v_1 + \frac{p}{2}\right) \left(v_2 + \frac{p}{2}\right)} \right\} \\
 &= \frac{\gamma}{\Theta} \operatorname{arc} \operatorname{tg} \frac{\Theta (v_1 - v_2)}{\Theta^2 + \left(v_1 + \frac{p}{2}\right) \left(v_2 + \frac{p}{2}\right)} \quad \dots \quad (5)
 \end{aligned}$$

or, if $v_2 = 0$:

$$t_1 = \frac{\gamma}{\Theta} \operatorname{arc} \operatorname{tg} \frac{\Theta v_1}{\Theta^2 + \left(v_1 + \frac{p}{2}\right) \frac{p}{2}} \quad \dots \quad (5')$$

$$\begin{aligned}
 l_1 &= -\gamma \int_{v_1}^{v_2} \frac{v dv}{v^2 + pv + q} \\
 &= \frac{\gamma}{2} \log_n \frac{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2}{\left(v_2 + \frac{p}{2}\right)^2 + \Theta^2} - \frac{p\gamma}{2\Theta} \operatorname{arc} \operatorname{tg} \frac{\Theta (v_1 - v_2)}{\Theta^2 + \left(v_1 + \frac{p}{2}\right) \left(v_2 + \frac{p}{2}\right)} \quad \dots \quad (6)
 \end{aligned}$$

$$= \frac{\gamma}{2} \log_n \frac{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2}{\left(v_2 + \frac{p}{2}\right)^2 + \Theta^2} - \frac{pt_1}{2} \quad \dots \quad (7)$$

or, if $v_2 = 0$:

$$l_1 = \frac{\gamma}{2} \log_n \frac{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2}{\left(\frac{p}{2}\right)^2 + \Theta^2} - \frac{p\gamma}{2\Theta} \operatorname{arc tg} \frac{\Theta v_1}{\Theta^2 + \left(v_1 + \frac{p}{2}\right) \frac{p}{2}} \quad (6')$$

$$l_1 = \frac{\gamma}{2} \log_n \frac{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2}{\left(\frac{p}{2}\right)^2 + \Theta^2} - \frac{p l_1}{2} \quad (7')$$

2) If values of v_1 and l_1 are given :

v_2 is obtained from equation (6) written thus :

$$\begin{aligned} l_1 &= -\frac{\gamma}{2} \log_n \frac{\left(v_2 + \frac{p}{2}\right)^2 + \Theta^2}{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2} - \frac{\gamma p}{2\Theta} \left[\operatorname{arc tg} \frac{v_1 + \frac{p}{2}}{\Theta} - \operatorname{arc tg} \frac{v_2 + \frac{p}{2}}{\Theta} \right] \\ &= -\frac{\gamma}{2} \log_n \frac{\left(v_2 + \frac{p}{2}\right)^2 + \Theta^2}{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2} - \frac{\gamma p}{2\Theta} \operatorname{arc tg} \frac{v_1 + \frac{p}{2}}{\Theta} + \frac{\gamma p}{2\Theta} \operatorname{arc tg} \frac{v_2 + \frac{p}{2}}{\Theta} \end{aligned}$$

from which :

$$\frac{\gamma p}{2\Theta} \operatorname{arc tg} \frac{v_2 + \frac{p}{2}}{\Theta} - \frac{\gamma}{2} \log_n \frac{\left(v_2 + \frac{p}{2}\right)^2 + \Theta^2}{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2} = l_1 + \frac{\gamma p}{2\Theta} \operatorname{arc tg} \frac{v_1 + \frac{p}{2}}{\Theta}$$

or :

$$\begin{aligned} \frac{\gamma p}{2\Theta} \operatorname{arc tg} \frac{v_2 + \frac{p}{2}}{\Theta} - \frac{\gamma}{2} \log_n \left\{ \left(v_2 + \frac{p}{2}\right)^2 + \Theta^2 \right\} &= l_1 + \frac{\gamma p}{2\Theta} \operatorname{arc tg} \frac{v_1 + \frac{p}{2}}{\Theta} \\ &\quad - \frac{\gamma}{2} \log_n \left\{ \left(v_1 + \frac{p}{2}\right)^2 + \Theta^2 \right\} \end{aligned}$$

or :

$$\begin{aligned} \frac{p}{\Theta} \operatorname{arc tg} \frac{v_2 + \frac{p}{2}}{\Theta} - \log_n \left\{ \left(v_2 + \frac{p}{2}\right)^2 + \Theta^2 \right\} &= \frac{2 l_1}{\gamma} + \frac{p}{\Theta} \operatorname{arc tg} \frac{v_1 + \frac{p}{2}}{\Theta} \\ &\quad - \log_n \left\{ \left(v_1 + \frac{p}{2}\right)^2 + \Theta^2 \right\} \quad (8) \end{aligned}$$

a transcendent equation from which the value of v_2 must be obtained by calculation.

$$\begin{aligned}
 \int_{v_1}^{v_2} \frac{v dv}{v^2 + pv + q} &= \int_{v_1}^{v_2} \frac{v dv}{\left(v + \frac{p}{2}\right)^2} = \frac{1}{2} \left[\frac{p}{v + \frac{p}{2}} + \log_n \left(v + \frac{p}{2}\right)^2 \right]_{v_1}^{v_2} \\
 &= \frac{1}{2} \left[\frac{p}{v_2 + \frac{p}{2}} - \frac{p}{v_1 + \frac{p}{2}} + \log_n \frac{\left(v_2 + \frac{p}{2}\right)^2}{\left(v_1 + \frac{p}{2}\right)^2} \right] \\
 &= \frac{1}{2} \left[\frac{p}{v_2 + \frac{p}{2}} - \frac{p}{v_1 + \frac{p}{2}} - \log_n \frac{\left(v_1 + \frac{p}{2}\right)^2}{\left(v_2 + \frac{p}{2}\right)^2} \right] \\
 &= \frac{1}{2} \left[\frac{p}{v_2 + \frac{p}{2}} - \frac{p}{v_1 + \frac{p}{2}} - 2 \log_n \frac{v_1 + \frac{p}{2}}{v_2 + \frac{p}{2}} \right]
 \end{aligned}$$

Under these conditions :

1) If values of v_1 and v_2 are given, we have :

$$\begin{aligned}
 t_1 &= -\gamma \int_{v_1}^{v_2} \frac{dv}{\left(v + \frac{p}{2}\right)^2} \\
 &= -\gamma \left[\frac{1}{v_1 + \frac{p}{2}} - \frac{1}{v_2 + \frac{p}{2}} \right] \\
 &= \gamma \left[\frac{1}{v_2 + \frac{p}{2}} - \frac{1}{v_1 + \frac{p}{2}} \right] \\
 &= \frac{\gamma (v_1 - v_2)}{\left(v_1 + \frac{p}{2}\right)\left(v_2 + \frac{p}{2}\right)} \dots \dots \dots (10)
 \end{aligned}$$

or, if $v_2 = 0$:

$$t_1 = \frac{\gamma v_1}{\left(v_1 + \frac{p}{2}\right)\frac{p}{2}} \dots \dots \dots (10')$$

$$\begin{aligned} l_1 &= -\gamma \int_{v_1}^{v_2} \frac{v dv}{\left(v + \frac{p}{2}\right)^2} \\ &= -\frac{\gamma}{2} \left[\frac{p}{v_2 + \frac{p}{2}} - \frac{p}{v_1 + \frac{p}{2}} - 2 \log_n \frac{\left(v_1 + \frac{p}{2}\right)}{\left(v_2 + \frac{p}{2}\right)} \right] \\ &= \gamma \log_n \frac{v_1 + \frac{p}{2}}{v_2 + \frac{p}{2}} + \frac{\gamma p}{2 \left(v_1 + \frac{p}{2}\right)} - \frac{\gamma p}{2 \left(v_2 + \frac{p}{2}\right)} \\ &= \gamma \log_n \frac{v_1 + \frac{p}{2}}{v_2 + \frac{p}{2}} + \frac{p \gamma (v_2 - v_1)}{2 \left(v_1 + \frac{p}{2}\right) \left(v_2 + \frac{p}{2}\right)} \\ &= \gamma \log_n \frac{v_1 + \frac{p}{2}}{v_2 + \frac{p}{2}} - \frac{p \gamma (v_1 - v_2)}{2 \left(v_1 + \frac{p}{2}\right) \left(v_2 + \frac{p}{2}\right)} \dots \dots \dots (11) \end{aligned}$$

$$= \gamma \log_n \frac{v_1 + \frac{p}{2}}{v_2 + \frac{p}{2}} - \frac{p t_1}{2} \dots \dots \dots (12)$$

or, if $v_2 = 0$:

$$\begin{aligned} l_1 &= \gamma \log_n \frac{v_1 + \frac{p}{2}}{\frac{p}{2}} - \frac{p \gamma v_1}{2 \left(v_1 + \frac{p}{2}\right) \frac{p}{2}} \\ &= \gamma \log_n \frac{2 \left(v_1 + \frac{p}{2}\right)}{p} - \frac{\gamma v_1}{v_1 + \frac{p}{2}} \dots \dots \dots (11') \end{aligned}$$

$$= \gamma \log_n \frac{2 \left(v_1 + \frac{p}{2}\right)}{p} - \frac{p t_1}{2} \dots \dots \dots (12')$$

2) If values of v_1 and l_1 are given :

v_2 is obtained from equation (11) written thus :

$$l_1 = \frac{\gamma p}{2 \left(v_1 + \frac{p}{2} \right)} - \frac{\gamma p}{2 \left(v_2 + \frac{p}{2} \right)} - \frac{\gamma}{2} \log_n \frac{\left(v_2 + \frac{p}{2} \right)^2}{\left(v_1 + \frac{p}{2} \right)^2}$$

or :

$$\frac{\gamma p}{2 \left(v_2 + \frac{p}{2} \right)} + \frac{\gamma}{2} \log_n \frac{\left(v_2 + \frac{p}{2} \right)^2}{\left(v_1 + \frac{p}{2} \right)^2} = \frac{\gamma p}{2 \left(v_1 + \frac{p}{2} \right)} - l_1$$

or :

$$\frac{p}{v_2 + \frac{p}{2}} + \log_n \frac{\left(v_2 + \frac{p}{2} \right)^2}{\left(v_1 + \frac{p}{2} \right)^2} = \frac{p}{v_1 + \frac{p}{2}} - \frac{2l_1}{\gamma}$$

or :

$$\frac{p}{v_2 + \frac{p}{2}} + 2 \log_n \left(v_2 + \frac{p}{2} \right) = 2 \log_n \left(v_1 + \frac{p}{2} \right) + \frac{p}{v_1 + \frac{p}{2}} - \frac{2l_1}{\gamma} \dots \dots \dots (13)$$

3) If values of v_1 and t_1 are given :

v_2 is obtained from equation (10) :

$$t_1 = \frac{\gamma (v_1 - v_2)}{\left(v_1 + \frac{p}{2} \right) \left(v_2 + \frac{p}{2} \right)}$$

from which :

$$\begin{aligned} v_2 &= \frac{\gamma v_1 - t_1 \left(v_1 + \frac{p}{2} \right) \frac{p}{2}}{t_1 \left(v_1 + \frac{p}{2} \right) + \gamma} \\ &= \frac{v_1 - \frac{p}{2\gamma} \left(v_1 + \frac{p}{2} \right) t_1}{1 + \frac{1}{\gamma} \left(v_1 + \frac{p}{2} \right) t_1} \dots \dots \dots (14) \end{aligned}$$

Note. — It will be noted when calculating time and distance travelled in the case of pure skidding at low speed of the order of 3 or 4 metres per second, per example, values of logarithms approaching unity are obtained which render the calculation difficult. In these cases, it is advisable to neglect the effect of

wind resistance which is very small at low speeds; and hence the differential equation for the transitory movement of the vehicle can be written thus :

$$M \frac{dv}{dt} = - \left\{ 1000 P (a' - b'v) \pm iP \right\} \text{ or : } \frac{dv}{dt} = - gb' \left(\frac{a'}{b'} \pm \frac{i}{1000 b'} - v \right)$$

$$\text{or, substituting : } s = \frac{a'}{b'} \pm \frac{i}{1000 b'} ; \quad \frac{dv}{dt} = - gb' (s - v)$$

from which :

$$dt = - \frac{1}{gb'} \times \frac{dv}{s - v}$$

from which :

$$t_1 = - \frac{1}{gb'} \int_{v_1}^{v_2} \frac{dv}{s - v}$$

$$= \frac{1}{gb'} \log_n \frac{s - v_2}{s - v_1}$$

$$\text{and } l_1 = \int_{v_1}^{v_2} v dt = - \frac{1}{gb'} \int_{v_1}^{v_2} \frac{v dv}{s - v}$$

$$= \frac{1}{gb'} \left\{ v_2 - v_1 + s \log_n \frac{s - v_2}{s - v_1} \right\}$$

$$= \frac{v_2 - v_1}{gb'} + \frac{s}{gb'} \log_n \frac{s - v_2}{s - v_1}$$

$$= \frac{s}{gb'} \log_n \frac{s - v_2}{s - v_1} - \frac{v_1 - v_2}{gb'}$$

$$= s t_1 - \frac{v_1 - v_2}{gb'}$$

If $v_2 = 0$, we have :

$$\begin{cases} t_1 = \frac{1}{gb'} \log_n \frac{s}{s - v_1} \\ l_1 = s t_1 - \frac{v_1}{gb'} \end{cases}$$

$$\text{For } i = 0 : s = \frac{a'}{b'} \pm \frac{i}{1000 b'} = \frac{a'}{b'} \pm 0 = \frac{a'}{b'}$$

so that for $v_2 = 0$ and $i = 0$, we find :

$$\begin{cases} t_1 = \frac{1}{gb'} \log_n \frac{a'}{a' - b'v_1} \\ l_1 = \frac{a'}{b'} t_1 - \frac{v_1}{gb'} = \frac{1}{b'} \left(a' t_1 - \frac{v_1}{g} \right) \end{cases}$$

PART II.

Period of Brake Cylinder Operation.

It is well known that a brief period of time (t_1) (2 to 3 seconds) must elapse from the moment the driver applies the brake until the actual application of the blocks upon the wheels reaches a value of $Q = KP$. During the elapse of this period of time, t_1 , the speed of the vehicle is reduced from v_1 to v_2 , a speed for which the braking effort is considered having reached the constant value $Q = KP$. The instantaneous speed of the vehicle after a period of time t_1 (taken from experience), together with the distance travelled during the same time, can be calculated bearing in mind that the braking effort (q tonnes) increases from zero to Q tonnes.

Now, in practice, it is found that the pressure in the brake cylinders rises quite rapidly at first, and afterwards more and more slowly. It follows that the law of increasing braking effort q as a function of time can be compared, without appreciable error, to a function of the second degree, and more particularly, to a function of an ellipse (a quarter ellipse where the concavity is turned towards the time axis).

Such a function can be expressed by the equation

$$t_1 q^2 + Q^2 (t_1 - t)^2 = t_1^2 Q^2$$

from which :

$$q = Q \sqrt{1 - \left(\frac{t_1 - t}{t_1}\right)^2}$$

$$= \frac{KP}{t_1} \sqrt{2 t_1 t - t^2}$$

Moreover, since the period of time, t_1 , under consideration, is so short, it can

be assumed that the value of the coefficient of friction between the brake shoes and tyres, and the value of wind resistance, vary little from those obtaining at the speed v_1 .

Under these conditions :

If $f = a - bv_1$ represents the value of the coefficient of friction at the speed v_1 ;

If $\beta S v_1^2$ represents the value of the overall wind resistance at the speed v_1 ;

the differential equation for the transitory movement of the vehicle can be written thus :

$$M \tau_1 \frac{dv}{dt} = - (1000 f q + \alpha P + \beta S v_1^2 \pm i P)$$

or, if R denotes the overall wind resistance $= \alpha P + \beta S v_1^2 \pm i P$:

$$M \tau_1 \frac{dv}{dt} = - (1000 f q + R)$$

$$\begin{aligned} \text{or } \frac{dv}{dt} &= - \frac{1}{M \tau_1} (1000 f q + R) \\ &= - \frac{g}{1000 P \tau_1} (1000 f q + R) \\ &= - \frac{g f q}{P \tau_1} - \frac{R}{1000 P \tau_1} \end{aligned}$$

$$\text{Substituting : } \begin{cases} A = \frac{g f}{P \tau_1} \\ B = \frac{g R}{1000 P \tau_1} = \frac{g \rho}{1000 \tau_1} \end{cases}$$

ρ denoting specific resistance of vehicle
 $= \frac{R}{P}$.

The above equation becomes :

$$\frac{dv}{dt} = - A q - B$$

from which :

$$dv = - A q dt - B dt \dots (1)$$

1) Calculation of speed v_2 .

Equation (1) gives:

$$\int_{v_1}^v dv = v - v_1 = -A \int_0^t q dt - B \int_0^t dt$$

from which :

$$v = v_1 - A \int_0^t q dt - Bt$$

or, replacing q by its value $\frac{AKP}{t_1} \sqrt{2t_1 t - t^2}$:

$$\begin{aligned} v &= v_1 - \frac{AKP}{t_1} \int_0^t \sqrt{2t_1 t - t^2} dt - Bt \\ &= v_1 - \frac{AKP}{t_1} \int_0^t \frac{2t_1 t - t^2}{\sqrt{2t_1 t - t^2}} dt - Bt \\ &= v_1 - \frac{AKP}{t_1} \left\{ 2t_1 \int_0^t \frac{t dt}{\sqrt{2t_1 t - t^2}} - \int_0^t \frac{t^2 dt}{\sqrt{2t_1 t - t^2}} \right\} - Bt \\ \int_0^t \frac{t dt}{\sqrt{2t_1 t - t^2}} &= -\sqrt{2t_1 t - t^2} + t_1 \text{ arc sin vers } \frac{t}{t_1} \dots \dots \dots (*) \\ \int_0^t \frac{t^2 dt}{\sqrt{2t_1 t - t^2}} &= -\sqrt{2t_1 t - t^2} \cdot \left(\frac{t}{2} + \frac{3t_1}{2} \right) + \frac{3}{2} t_1^2 \text{ arc sin vers } \frac{t}{t_1} \end{aligned}$$

so that writing provisionally :

$$\sqrt{2t_1 t - t^2} = \sqrt{\Theta}$$

we have :

$$\begin{aligned} \int_0^t \frac{t dt}{\sqrt{2t_1 t - t^2}} &= -\sqrt{\Theta} + t_1 \text{ arc sin vers } \frac{t}{t_1} \\ \int_0^t \frac{t^2 dt}{\sqrt{2t_1 t - t^2}} &= -\sqrt{\Theta} \left(\frac{t}{2} + \frac{3t_1}{2} \right) + \frac{3}{2} t_1^2 \text{ arc sin vers } \frac{t}{t_1} \\ &= -\frac{t}{2} \sqrt{\Theta} - \frac{3t_1}{2} \sqrt{\Theta} + \frac{3}{2} t_1^2 \text{ arc sin vers } \frac{t}{t_1} \end{aligned}$$

(*) « arc sin vers » means « versine-1 ».

$$\begin{aligned}
 &= v_1 t_1 - \frac{\text{AKP}}{t_1} \left[\frac{1}{2} \int_0^{t_1} t \sqrt{\Theta} dt - \frac{t_1}{2} \int_0^{t_1} \sqrt{\Theta} dt + \frac{t_1^2}{2} \int_0^{t_1} \text{arc sin vers } \frac{t}{t_1} dt \right] - \frac{\text{B}t_1^2}{2} \\
 &= v_1 t_1 - \frac{\text{AKP}}{t_1} \left[\frac{1}{2} \int_0^{t_1} \frac{t \Theta}{\sqrt{\Theta}} dt - \frac{t_1}{2} \int_0^{t_1} \frac{\Theta}{\sqrt{\Theta}} dt + \frac{t_1^2}{2} \int_0^{t_1} \text{arc sin vers } \frac{t}{t_1} dt \right] - \frac{\text{B}t_1^2}{2}
 \end{aligned}$$

expression in which :

$$\begin{aligned}
 \frac{1}{2} \int_0^{t_1} \frac{t \Theta}{\sqrt{\Theta}} dt &= \frac{1}{2} \int_0^{t_1} \frac{t(2t_1 t - t^2)}{\sqrt{\Theta}} dt = \frac{1}{2} \int_0^{t_1} \frac{2t_1 t^2}{\sqrt{\Theta}} dt - \frac{1}{2} \int_0^{t_1} \frac{t^3}{\sqrt{\Theta}} dt \\
 &= t_1 \int_0^{t_1} \frac{t^2 dt}{\sqrt{\Theta}} - \frac{1}{2} \int_0^{t_1} \frac{t^3 dt}{\sqrt{\Theta}} \\
 \frac{t_1}{2} \int_0^{t_1} \frac{\Theta}{\sqrt{\Theta}} dt &= \frac{t_1}{2} \int_0^{t_1} \frac{2t_1 t - t^2}{\sqrt{\Theta}} dt = \frac{t_1}{2} \int_0^{t_1} \frac{2t_1 t}{\sqrt{\Theta}} dt - \frac{t_1}{2} \int_0^{t_1} \frac{t^2 dt}{\sqrt{\Theta}} \\
 &= t_1^2 \int_0^{t_1} \frac{t dt}{\sqrt{\Theta}} - \frac{t_1}{2} \int_0^{t_1} \frac{t^2 dt}{\sqrt{\Theta}}
 \end{aligned}$$

So that :

$$\begin{aligned}
 l_1 = v_1 t_1 - \frac{\text{AKP}}{t_1} \left[t_1 \int_0^{t_1} \frac{t^2 dt}{\sqrt{\Theta}} - \frac{1}{2} \int_0^{t_1} \frac{t^3 dt}{\sqrt{\Theta}} - t_1^2 \int_0^{t_1} \frac{t dt}{\sqrt{\Theta}} + \frac{t_1}{2} \int_0^{t_1} \frac{t^2 dt}{\sqrt{\Theta}} \right. \\
 \left. + \frac{t_1^2}{2} \int_0^{t_1} \text{arc sin vers } \frac{t}{t_1} dt \right] - \frac{\text{B}t_1^2}{2}
 \end{aligned}$$

$$= v_1 t_1 - \frac{\text{AKP}}{t_1} \left[-\frac{1}{2} \int_0^{t_1} \frac{t^3 dt}{\sqrt{\Theta}} + \frac{3}{2} t_1 \int_0^{t_1} \frac{t^2 dt}{\sqrt{\Theta}} - t_1^2 \int_0^{t_1} \frac{t dt}{\sqrt{\Theta}} + \frac{t_1^2}{2} \int_0^{t_1} \text{arc sin vers } \frac{t}{t_1} dt \right] - \frac{\text{B} t_1^2}{2}$$

We find :

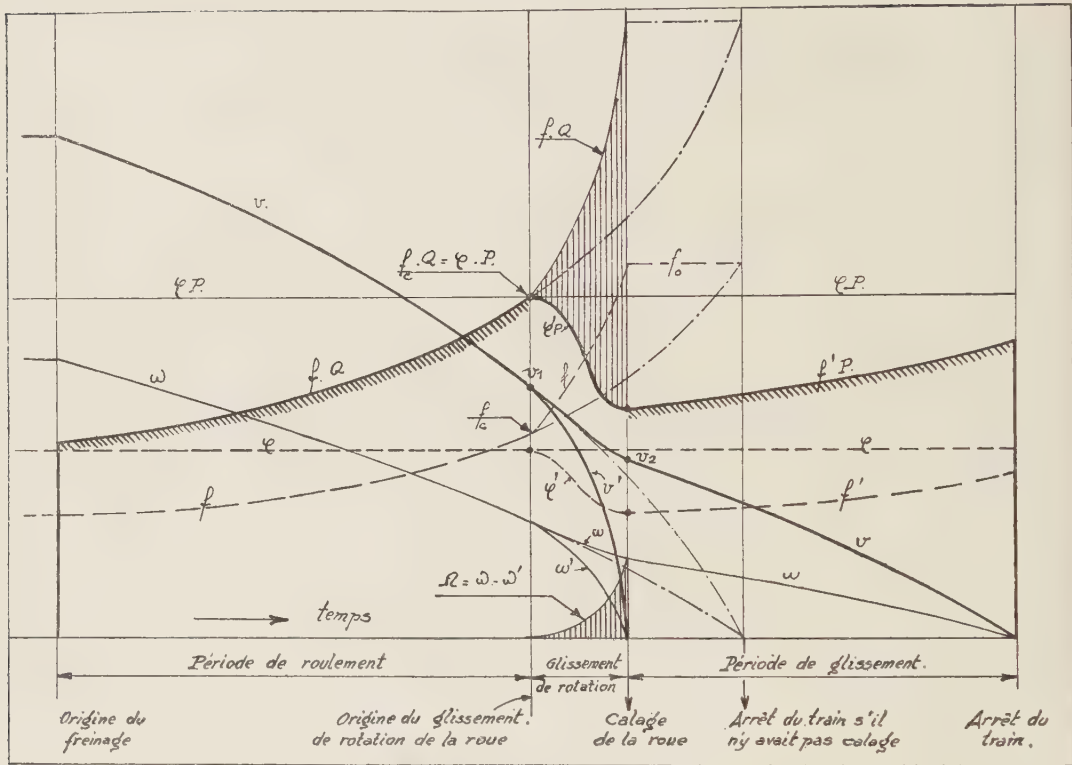
$$\begin{aligned} \int_0^{t_1} \frac{t^3 dt}{\sqrt{2t_1 t - t^2}} &= \left[-\sqrt{2t_1 t - t^2} \left(\frac{t^2}{3} + \frac{5}{6} t_1 t + \frac{15}{6} t_1^2 \right) + \frac{15}{6} t_1^3 \text{arc sin vers } \frac{t}{t_1} \right]_{t_1}^{t_1} \\ &= -\sqrt{2t_1 t_1 - t_1^2} \left(\frac{t_1^2}{3} + \frac{5}{6} t_1^2 + \frac{15}{6} t_1^2 \right) + \frac{15}{6} t_1^3 \text{arc sin vers } \frac{t_1}{t_1} \\ &= -t_1 \left(\frac{22}{6} t_1^2 \right) + \frac{15}{6} t_1^3 \cdot \frac{\pi}{2} \\ &= -\frac{22}{6} t_1^3 + \frac{15}{12} \pi t_1^3 \\ &= \left(\frac{15}{12} \pi - \frac{22}{6} \right) t_1^3 \\ &= \left(\frac{5}{4} \pi - \frac{22}{6} \right) t_1^3 \\ \int_0^{t_1} \frac{t^2 dt}{\sqrt{2t_1 t - t^2}} &= \left[-\sqrt{2t_1 t - t^2} \left(\frac{t_1}{2} + \frac{3t_1}{2} \right) + \frac{3}{2} t_1^2 \text{arc sin vers } \frac{t}{t_1} \right]_{t_1}^{t_1} \\ &= -t_1 \cdot 2t_1 + \frac{3}{2} t_1^2 \text{arc sin vers } \frac{t_1}{t_1} \\ &= -2t_1^2 + \frac{3}{2} t_1^2 \cdot \frac{\pi}{2} \\ &= -2t_1^2 + \frac{3}{4} \pi t_1^2 \\ &= \left(\frac{3}{4} \pi - 2 \right) t_1^2 \end{aligned}$$

$$\begin{aligned}
 \int_0^{t_1} \frac{t dt}{\sqrt{2t_1 t - t^2}} &= \left[-\sqrt{2t_1 t - t^2} + t_1 \operatorname{arc sin vers} \frac{t}{t_1} \right]_0^{t_1} \\
 &= -\sqrt{2t_1 t_1 - t_1^2} + t_1 \operatorname{arc sin vers} \frac{t_1}{t_1} \\
 &= -\sqrt{2t_1^2 - t_1^2} + t_1 \frac{\pi}{2} \\
 &= \left(\frac{\pi}{2} - 1 \right) t_1
 \end{aligned}$$

$$\int_0^{t_1} \operatorname{arc sin vers} \frac{t}{t_1} dt = t_1 \left[\left(\frac{t}{t_1} - 1 \right) \operatorname{arc sin vers} \frac{t}{t_1} + \sqrt{2 \frac{t}{t_1} - \left(\frac{t}{t_1} \right)^2} \right]_0^{t_1} = t_1$$

Consequently :

$$\begin{aligned}
 l_1 &= v_1 t_1 - \frac{\text{AKP}}{t_1} \left[-\frac{4}{2} \left(\frac{5}{4} \pi - \frac{22}{6} \right) t_1^3 + \frac{3}{2} t_1 \left(\frac{3}{4} \pi - 2 \right) t_1^2 \right. \\
 &\quad \left. - t_1^2 \left(\frac{\pi}{2} - 1 \right) t_1 + \frac{t_1^2}{2} \cdot t_1 \right] - \frac{\text{B} t_1^2}{2} \\
 &= v_1 t_1 - \frac{\text{AKP}}{t_1} \times \frac{1}{3} t_1^3 - \frac{1}{2} \text{B} t_1^2 \\
 &= v_1 t_1 - \frac{1}{3} \text{AKP} t_1^2 - \frac{1}{2} \text{B} t_1^2 \\
 &= v_1 t_1 - \left(\frac{\text{AKP}}{3} + \frac{\text{B}}{2} \right) t_1^2 \\
 &= v_1 t_1 - \left(\frac{gf\text{KP}}{3 \text{P}\eta} + \frac{g\text{R}}{2 \times 1000 \text{P}\eta} \right) t_1^2 \\
 &= v_1 t_1 - \frac{g}{\eta} \left(\frac{1}{3} f\text{K} + \frac{\text{R}}{2000 \text{P}} \right) t_1^2 \\
 &= v_1 t_1 - \frac{g}{\eta} \left(\frac{1}{3} f\text{K} + 0.0005 \rho \right) t_1^2 \quad \dots \dots \dots (11)
 \end{aligned}$$



Explanation of French terms :

Origine du freinage = beginning of braking period. — Temps = time. — Période de roulement = period of rolling. — Origine du glissement de rotation de la roue = beginning of period of skidding and rotating of the wheels. — Glissement de rotation = skidding and rotation. — Calage de la roue = locking of wheels. — Période de glissement = period of skidding. — Arrêt du train s'il n'y avait pas calage = stopping of train if there were no locking of the wheels. — Arrêt du train = stopping of train.

PART III.

The transitional period between pure rolling before wheels are locked, and pure skidding after wheels are locked.

Consider a pair of wheels acted upon by a retarding torque with an increasing value.

It is well known that if, at any instant, the retarding torque reaches and exceeds a certain value, dependent upon the adhesion of wheels on the rail, the wheels will commence to skid whilst at the same time continuing to rotate for a very short

time; their speed of rotation diminishing rapidly until it becomes zero. The wheels are then said to be locked. These particular conditions, in such case, constitute the transitional period between pure rolling and pure skidding after the locking of the wheels.

In this instance it is necessary to determine :

- The duration of this period;
- The speed of the vehicle at the end of this period;
- The distance travelled by the vehicle during this period.

Let v' denote the instantaneous peripheral velocity of the wheels during the period and ω' the corresponding angular velocity, so that $\omega' = \frac{v'}{r}$.

Let v denote the instantaneous speed of the vehicle during the period and ω the corresponding angular velocity of the wheels were they not skidding, so that in this case $\omega = \frac{v}{r}$.

And finally if v_1 and v_2 represent the speed of the vehicle at the beginning and ending of the period respectively;

During the period, the speed of the vehicle (v) falls from v_1 to v_2 .

At the beginning of the period $v' = v_1$ and $\omega' = \frac{v_1}{r}$, while at the end of the period $v' = 0$ and $\omega' = 0$.

At any moment during the period, we have :

$$v' < v \text{ and } \omega' = \frac{v'}{r} < \omega = \frac{v}{r}$$

While v falls from v_1 to v_2 , v' falls from v_1 to zero.

While ω (assumed value) falls from $\frac{v_1}{r}$ to $\frac{v_2}{r}$, ω' falls from $\frac{v_1}{r}$ to zero.

At every moment, during the period, therefore, a skid is produced =

$$\omega - \omega' = \frac{v}{r} - \frac{v'}{r}$$

Denoting the instantaneous value of this skidding by Ω (expressed in radians per second), we have :

$$\begin{aligned} \Omega &= \omega - \omega' \\ &= \frac{v}{r} - \frac{v'}{r} \end{aligned}$$

Commencing at zero, this skidding increases rapidly in proportion as ω' decreases, and in a very short time, reaches

its maximum value at the instant when $\omega' = 0$.

Thus, at the beginning of the period :

$$\Omega = \omega - \omega' = \frac{v_1}{r} - \frac{v_1}{r} = 0$$

— During the period :

$$\Omega = \omega - \omega' = \frac{v}{r} - \frac{v'}{r}$$

— At the end of the period :

$$\Omega = \omega - \omega' = \frac{v_2}{r} - 0 = \frac{v_2}{r}$$

This stated, let φ denote the instantaneous coefficient of adhesion, function of the speed of translation (v) of the vehicle.

Let P' kilogrammes equal the weight transmitted by the train of wheels upon the rails, and Q' kilogrammes the pressure of the brake blocks on the same train of wheels. Then we have $K = \frac{Q'}{P'} = \frac{Q}{P}$.

The skidding $\Omega = \omega - \omega'$ occurs at the moment when in consequence of the reduction of peripheral velocity of the wheels, the braking effort due to friction fQ' of the blocks upon the wheels equals the instantaneous value $\varphi P'$ of adhesion of wheels upon rail, i.e. at the instant that the coefficient of friction f of the brake blocks on the wheels reaches a certain value f_c so that :

$$f_c Q' = \varphi P'$$

from which :

$$\begin{aligned} f_c &= \frac{\varphi P'}{Q'} \\ &= \frac{\varphi}{K} \end{aligned}$$

a value to which a peripheral velocity v_1 of the wheels corresponds and therefore a vehicle speed v_1 so that :

$$a - bv_1 = \frac{\varphi}{K}$$

from which :

$$v_1 = \frac{1}{b} \left(a - \frac{\varphi}{K} \right)$$

which shows that :

$$\text{— If } \frac{\varphi}{K} \geq a,$$

v_1 is negative or zero, indicating that any question of the locking of wheels must be excluded.

$$\text{— If } \frac{\varphi}{K} < a,$$

v_1 is positive, indicating the possibility of wheel skidding which precedes the locking of the wheels.

In the latter event, skidding of the wheels will commence at the moment the speed of the vehicle will have reached the value

$$v_1 = \frac{1}{b} \left(a - \frac{\varphi}{K} \right)$$

(which may be called the « critical » speed of braking).

Hence, if the values K and φ are given, it is sufficient to compare values of $\frac{\varphi}{K}$ and a in order to determine conditions of skid before proceeding with the above calculation.

* * *

Considering the movement of a train of wheels during the transitional period in the case where $\frac{\varphi}{K} < a$, the coefficient of friction f during this very short period no longer depends upon the speed of the vehicle (v) but upon the peripheral speed of the wheels (v'), thus $f = a$

Also f increases rapidly from the value given by $f = a - bv_1$ (beginning of the

period) to that given by $f = a$ (end of the period) provided that the speed v' is within the limits $v' = v_1$ (beginning of period) and $v' = 0$ (end of period).

On the contrary the tangential reaction from the rail decreases and rapidly falls from the value $\varphi P'$ due to adhesion (corresponding to speed v_1) to that of $f'P'$ due to reaction from pure skidding (corresponding to speed v_2).

Let $\varphi'P'$ denote the instantaneous value of this reaction during the period.

Then the coefficient φ' decreases consequently from φ to f' .

In a similar manner the straight line law of the decrease in the value of φ' in relation to peripheral velocity v' can be stated thus :

$$\varphi' = m + nv'$$

in which :

$$\varphi' = \varphi \text{ for } v' = v_1 \text{ and } v = v_1$$

$$\varphi' = f' \text{ for } v' = 0 \text{ and } v = v_2$$

$$\text{The equations } \begin{cases} m + nv_1 = \varphi \\ m + 0 = f' \end{cases}$$

$$\text{give } \begin{cases} m = f' \\ n = \frac{\varphi - f'}{v_1} \end{cases}$$

It will be noted that the value $f' = a' - b'v_2$ (in the present case) can be approximately taken as equal to $f' = a' - b'v_1$, provided that the speed v_2 is little different from v_1 .

Under these conditions, and having regard to what has already been stated, the differential equation for the rotation of a train of wheels in the case under consideration can be written thus

$$I \frac{d\Omega}{dt} = (fQ' - \varphi'P') r$$

in which :

I = the mass moment of inertia of the wheels expressed in kgr. $\times$ m. $\times$ sec².

r = radius of wheels in metres.

Ω = skidding = $\omega - \omega'$ expressed in radians per second.

Substituting f and φ' by their respective values $f = a - bv'$ and $\varphi' = m + nv'$, the above equation becomes :

$$\frac{I}{r} \frac{d\Omega}{dt} = (a - bv') Q' - (m + nv') P'$$

or :

$$\frac{I}{r} \frac{d\Omega}{dt} = aQ' - mP' - (bQ' + nP') v'$$

but :

$$\begin{aligned} \frac{I}{r} \frac{d\Omega}{dt} &= \frac{I}{r} \cdot \frac{d(\omega - \omega')}{dt} \\ &= \frac{I}{r} \frac{d\left(\frac{v}{r} - \frac{v'}{r}\right)}{dt} \\ &= \frac{I}{r^2} \left(\frac{dv}{dt} - \frac{dv'}{dt} \right) \end{aligned}$$

we have finally :

$$\frac{I}{r^2} \left(\frac{dv}{dt} - \frac{dv'}{dt} \right) = aQ' - mP' - (bQ' + nP') v' \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Since wind resistance varies little between the speeds v_1 and v_2 as these speeds are very little different from each other, its value can be taken as constant and equal to $\beta S v_1^2$ from which the differential equation for the movement of the *vehicle* can be written thus :

$$M \frac{dv}{dt} = - (1000 \varphi' P + \alpha P + \beta S v_1^2 \pm i P)$$

or, substituting : $\alpha P + \beta S v_1^2 \pm i P = \rho . P = \text{constant}$, ρ being the specific resistance of the vehicle at the speed v_1 :

$$M \frac{dv}{dt} = - (1000 \varphi' P + \rho P)$$

or :

$$\frac{1000 P}{g} \frac{dv}{dt} = - (1000 \varphi' + \rho) . P$$

2) *Calculation of the speed v_2 .*

Equation (2) gives :

$$dv = - \frac{g \{ 1000 (m + nv') + \rho \}}{1000} dt$$

or, replacing dt by its value (3) :

$$dv = \frac{gI}{r^2} \times \frac{1000 (m + nv') + \rho}{1000} \times \frac{dv'}{B - Av'}$$

and then :

$$\int_{v_1}^v dv = \int_{v_1}^{v'} \frac{gI}{r^2} \times \frac{1000 (m + nv') + \rho}{1000} \times \frac{dv'}{B - Av'}$$

or :

$$\begin{aligned} v - v_1 &= \frac{gI}{r^2} \int_{v_1}^{v'} \left\{ m \frac{dv'}{B - Av'} + nv' \frac{dv'}{B - Av'} + \frac{\rho}{1000} \frac{dv'}{B - Av'} \right\} \\ &= \frac{gIm}{r^2} \int_{v_1}^{v'} \frac{dv'}{B - Av'} + \frac{gIn}{r^2} \int_{v_1}^{v'} \frac{v' dv'}{B - Av'} + \frac{gI\rho}{1000 r^2} \int_{v_1}^{v'} \frac{dv'}{B - Av'} \\ v &= v_1 + \frac{gI}{r^2} \left(m + \frac{\rho}{1000} \right) \int_{v_1}^{v'} \frac{dv'}{B - Av'} + \frac{gIn}{r^2} \int_{v_1}^{v'} \frac{v' dv'}{B - Av'} \end{aligned}$$

or, if :

$$\lambda = \frac{gI}{r^2} \left(m + \frac{\rho}{1000} \right)$$

$$\lambda' = \frac{gIn}{r^2}$$

$$v = v_1 + \lambda \int_{v_1}^{v'} \frac{dv'}{B - Av'} + \lambda' \int_{v_1}^{v'} \frac{v' dv'}{B - Av'}$$

or :

$$\begin{aligned} v &= v_1 - \frac{\lambda}{A} \log_n \frac{B - Av'}{B - Av_1} - \frac{\lambda'}{A^2} \left(Av' - Av_1 + B \log_n \frac{B - Av'}{B - Av_1} \right) \\ &= v_1 - \frac{\lambda}{A} \log_n \frac{B - Av'}{B - Av_1} - \frac{\lambda'}{A} (v' - v_1) - \frac{\lambda' B}{A^2} \log_n \frac{B - Av'}{B - Av_1} \\ &= \left(1 + \frac{\lambda}{A} \right) v_1 - \frac{\lambda'}{A} v' - \left(\frac{\lambda}{A} + \frac{\lambda' B}{A^2} \right) \log_n \frac{B - Av'}{B - Av_1} \quad . \quad . \quad . \quad . \quad . \quad (5) \end{aligned}$$

When $v' = 0$, we find :

$$v_2 = \left(1 + \frac{\lambda'}{A}\right)v_1 - \left(\frac{\lambda}{A} + \frac{\lambda'B}{A^2}\right)\log_n \frac{B}{B - Av_1} \quad (6)$$

3) *Calculation of distance travelled l_1 .*

The equation $dl = v dt$, replacing v by its value (5) and dt by its value (3) :

$$\begin{aligned} dl &= - \left\{ \left(1 + \frac{\lambda'}{A}\right)v_1 - \frac{\lambda'v'}{A} - \left(\frac{\lambda}{A} + \frac{\lambda'B}{A^2}\right)\log_n \frac{B - Av'}{B - Av_1} \right\} \frac{1}{r^2} \cdot \frac{dv'}{B - Av'} \\ &= \frac{1}{r^2} \left\{ - \left(1 + \frac{\lambda'}{A}\right)v_1 + \frac{\lambda'v'}{A} + \left(\frac{\lambda}{A} + \frac{\lambda'B}{A^2}\right) \left[\log_n (B - Av') - \log_n (B - Av_1) \right] \right\} \frac{dv'}{B - Av'} \\ &= \frac{1}{r^2} \left\{ - \left(1 + \frac{\lambda'}{A}\right)v_1 + \frac{\lambda'v'}{A} + \left(\frac{\lambda}{A} + \frac{\lambda'B}{A^2}\right) \log_n (B - Av') \right. \\ &\quad \left. - \left(\frac{\lambda}{A} + \frac{\lambda'B}{A^2}\right) \log_n (B - Av_1) \right\} \frac{dv'}{B - Av'} \\ &= \frac{1}{r^2} \left\{ - \left(1 + \frac{\lambda'}{A}\right)v_1 - \left(\frac{\lambda}{A} + \frac{\lambda'B}{A^2}\right) \log_n (B - Av_1) + \frac{\lambda'v'}{A} \right. \\ &\quad \left. + \left(\frac{\lambda}{A} + \frac{\lambda'B}{A^2}\right) \log_n (B - Av') \right\} \frac{dv'}{B - Av'} \\ &= \frac{1}{r^2 A} \left\{ - (A + \lambda') v_1 - \left(\lambda + \frac{\lambda'B}{A}\right) \log_n (B - Av_1) + \lambda'v' \right. \\ &\quad \left. + \left(\lambda + \frac{\lambda'B}{A}\right) \log_n (B - Av') \right\} \frac{dv'}{B - Av'} \end{aligned}$$

or, if :

$$\begin{cases} \alpha = (A + \lambda') v_1 + \left(\lambda + \frac{\lambda'B}{A}\right) \log_n (B - Av_1) \\ \beta = \lambda' \\ \gamma = \lambda + \frac{\lambda'B}{A} \end{cases}$$

$$\begin{aligned} dl &= \frac{1}{r^2 A} \left\{ - \alpha + \beta v' + \gamma \log_n (B - Av') \right\} \frac{dv'}{B - Av'} \\ &= \frac{1}{r^2 A} \left\{ - \frac{\alpha dv'}{B - Av'} + \frac{\beta v' dv'}{B - Av'} + \frac{\gamma \log_n (B - Av')}{B - Av'} \right\} \end{aligned}$$

from which :

$$\begin{aligned}
 l_1 &= \frac{I}{r^2 A} \left\{ -\alpha \int_{v_1}^0 \frac{dv'}{B - Av'} + \beta \int_{v_1}^0 \frac{v' dv'}{B - Av'} + \gamma \int_{v_1}^0 \frac{\log_n (B - Av') dv'}{B - Av'} \right. \\
 &= \frac{I}{r^2 A} \left\{ \frac{\alpha}{A} \left[\log_n (B - Av') \right]_{v_1}^0 + \frac{\beta}{A^2} \left[B - Av' - B \log_n (B - Av') \right]_{v_1}^0 \right. \\
 &\quad \left. - \frac{\gamma}{2A} \left[\log_n^2 (B - Av') \right]_{v_1}^0 \right\} \\
 &= \frac{I}{r^2 A} \left\{ \frac{\alpha}{A} \left[\log_n B - \log_n (B - Av_1) \right] + \frac{\beta}{A^2} \left[Av_1 + B \log_n (B - Av_1) - B \log_n B \right] \right. \\
 &\quad \left. - \frac{\gamma}{2A} \left[\log_n^2 B - \log_n^2 (B - Av_1) \right] \right\} \\
 &= \frac{I}{r^2 A^2} \left\{ \alpha \log_n \frac{B}{B - Av_1} + \frac{\beta}{A} \left(Av_1 - B \log_n \frac{B}{B - Av_1} \right) \right. \\
 &\quad \left. - \frac{\gamma}{2} \left[\log_n B + \log_n (B - Av_1) \right] \left[\log_n B - \log_n (B - Av_1) \right] \right\} \\
 &= \frac{I}{r^2 A^2} \left\{ \alpha \log_n \frac{B}{B - Av_1} + \beta v_1 - \frac{\beta B}{A} \log_n \frac{B}{B - Av_1} \right. \\
 &\quad \left. - \frac{\gamma}{2} \log_n B (B - Av_1) \log_n \frac{B}{B - Av_1} \right\} \\
 &= \frac{I}{r^2 A^2} \left\{ \left[\alpha - \frac{\beta B}{A} - \frac{\gamma}{2} \log_n B (B - Av_1) \right] \log_n \frac{B}{B - Av_1} + \beta v_1 \right\} \quad (7)
 \end{aligned}$$

SUMMARY

PART I.

A) Value of the parametres γ , p and q .

I. Autovvariable brake.

$$\begin{aligned}
 \gamma &= \frac{1000 P \eta}{g (\beta S - 1000 kb)} \\
 p &= \frac{1000 (ka - KPb + k'b)}{\beta S - 1000 kb} \\
 q &= \frac{1000 (KP - k') a + \alpha P \pm i P}{\beta S - 1000 kb}
 \end{aligned}$$

II. Constant pressure brake.

$$\begin{aligned}
 \gamma &= \frac{1000 P \eta}{g \beta S} \\
 p &= - \frac{1000 K b P}{\beta S} \\
 q &= \frac{(1000 Ka + \alpha \pm i) P}{\beta S}
 \end{aligned}$$

III. Skidding with locked wheels.

$$\begin{aligned}
 \gamma &= \frac{1000 P}{g \beta S} \\
 p &= - \frac{1000 b' P}{\beta S} \\
 q &= \frac{(1000 a' \pm i) P}{\beta S}
 \end{aligned}$$

B) Value of t_1 , l_1 and v_2 .

1st case: $\frac{p^2}{4} - q > 0$.

$$\text{We write: } \sqrt{\frac{p^2}{4} - q} = \Delta \text{ and } \begin{cases} A = -\left(\Delta + \frac{p}{2}\right) \\ B = \Delta - \frac{p}{2} \end{cases}$$

1) If v_1 and v_2 are given.

$$a) t_1 = \frac{\gamma}{2\Delta} \left[\log_n \frac{A - v_2}{A - v_1} - \log_n \frac{B - v_2}{B - v_1} \right] \dots \dots \dots (1)$$

$$b) l_1 = \frac{\gamma}{2\Delta} \left[A \log_n \frac{A - v_2}{A - v_1} - B \log_n \frac{B - v_2}{B - v_1} \right] \dots \dots \dots (2)$$

2) If v_1 and l_1 are given.

a) v_2 is obtained from the equation:

$$A \log_n (A - v_2) - B \log_n (B - v_2) = \frac{2\Delta l_1}{\gamma} - \varepsilon \dots \dots \dots (3)$$

in which $\varepsilon = B \log_n (B - v_1) - A \log_n (A - v_1)$.

$$b) t_1 = (1)$$

3) If v_1 and t_1 are given.

$$a) v_2 = \frac{\varepsilon B - A}{\varepsilon - 1} \dots \dots \dots (4)$$

expression in which $\varepsilon = \frac{A - v_1}{B - v_2} \cdot e^{\frac{2\Delta t_1}{\gamma}}$

$$b) l_1 = (2)$$

2nd case: $\frac{p^2}{4} - q < 0$.

$$\text{We write } \sqrt{q - \frac{p^2}{4}} = \Theta$$

1) If v_1 and v_2 are given.

$$a) t_1 = \frac{\gamma}{\Theta} \operatorname{arc} \operatorname{tg} \frac{\Theta (v_1 - v_2)}{\Theta^2 + \left(v_1 + \frac{p}{2}\right) \left(v_2 + \frac{p}{2}\right)} \dots \dots \dots (5)$$

$$b) l_1 = \frac{\gamma}{2} \log_n \frac{\left(v_1 + \frac{p}{2}\right)^2 + \Theta^2}{\left(v_2 + \frac{p}{2}\right)^2 + \Theta^2} - \frac{p\gamma}{2\Theta} \operatorname{arc} \operatorname{tg} \frac{\Theta (v_1 - v_2)}{\Theta^2 + \left(v_1 + \frac{p}{2}\right) \left(v_2 + \frac{p}{2}\right)} \dots \dots \dots (6)$$

$$= \frac{\gamma}{2} \log_n \left(\frac{v_1 + \frac{p}{2}}{v_2 + \frac{p}{2}} + \Theta^2 \right) - \frac{pt_1}{2} \dots \dots \dots (7)$$

2) If v_1 and l_1 are given.

a) v_2 is obtained from the equation :

$$\frac{p}{\Theta} \operatorname{arc} \operatorname{tg} \frac{v_2 + \frac{p}{2}}{\Theta} - \log_n \left\{ v_2 + \frac{p}{2} + \Theta^2 \right\} = \frac{2l}{\gamma} + \frac{p}{\Theta} \operatorname{arc} \operatorname{tg} \frac{v_1 + \frac{p}{2}}{\Theta} - \log_n \left\{ v_1 + \frac{p}{2} + \Theta^2 \right\} \dots \dots (8)$$

b) $t_1 = (5)$

3) If v_1 and t_1 are given.

$$a) v_2 = \frac{v_1 + \frac{p}{2} - \Theta \operatorname{tg} \frac{\Theta t_1}{\gamma}}{1 + \frac{v_1 + \frac{p}{2}}{\Theta} \operatorname{tg} \frac{\Theta t_1}{\gamma}} - \frac{p}{2} \dots \dots \dots (9)$$

b) $l_1 = (7)$

3rd case : $\frac{p^2}{4} - q = 0$.

1) If v_1 and v_2 are given.

$$a) t_1 = \frac{\gamma (v_1 - v_2)}{\left(v_1 + \frac{p}{2} \right) \left(v_2 + \frac{p}{2} \right)} \dots \dots \dots (10)$$

$$b) l_1 = \gamma \log_n \frac{v_1 + \frac{p}{2}}{v_2 + \frac{p}{2}} - \frac{p \gamma (v_1 - v_2)}{2 \left(v_1 + \frac{p}{2} \right) \left(v_2 + \frac{p}{2} \right)} \dots \dots \dots (11)$$

$$= \gamma \log_n \frac{v_1 + \frac{p}{2}}{v_2 + \frac{p}{2}} - \frac{pt_1}{2} \dots \dots \dots (12)$$

2) If v_1 and l_1 are given.

a) v_2 is obtained from the equation :

$$\frac{p}{v_2 + \frac{p}{2}} + 2 \log_n \left(v_2 + \frac{p}{2} \right) = 2 \log_n \left(v_1 + \frac{p}{2} \right) + \frac{p}{v_1 + \frac{p}{2}} - \frac{2l_1}{\gamma} \dots \dots \dots (13)$$

b) $t_1 = (10)$

3) If v_1 and t_1 are given.

$$a) v_2 = \frac{v_1 - \frac{p}{2} \left(v_1 + \frac{p}{2} \right) t_1}{1 + \frac{1}{\gamma} \left(v_1 + \frac{p}{2} \right) t_1}$$

$$b) l_1 = (12)$$

C) *Particular case of skidding at low speed.*

$$s = \frac{a'}{b'} \pm \frac{i}{1000 b'}$$

$$\text{If } v_2 > 0 \left\{ \begin{array}{l} t_1 = \frac{1}{gb'} \log_n \frac{s - v_2}{s - v_1} \\ l_1 = st_1 - \frac{v_1 - v_2}{gb'} \end{array} \right.$$

$$\text{If } v_2 = 0 \left\{ \begin{array}{l} t_1 = \frac{1}{gb'} \log_n \frac{s}{s - v_1} \\ l_1 = st_1 - \frac{v_1}{gb'} \end{array} \right.$$

$$\text{If } v_2 = 0 \text{ and } i = 0 \left\{ \begin{array}{l} t_1 = \frac{1}{gb'} \log_n \frac{a'}{a' - b'v_1} \\ l_1 = \frac{1}{b'} \left(a't_1 - \frac{v_1}{g} \right) \end{array} \right.$$

PART II.

Period of brake cylinder operation.

Given the speed at the beginning of the period v_1 and length of time of the period t_1 , find the speed at the end of period v_2 and distance travelled (l_1).

We find :

$$a) v_2 = v_1 - \frac{g}{\tau_1} \left(\frac{\pi}{4} fK + 0.001 \rho \right) t_1$$

$$b) l_1 = v_1 t_1 - \frac{g}{\tau_1} \left(\frac{1}{3} fK + 0.0003 \rho \right) t_1^2$$

PART III.

Transitional Period.

Given the speed at the beginning of the period v_1 .

Find :

a) the time t_1 of the period;

b) the speed v_2 at the end of the period;

c) the distance l_1 travelled during the period.

Knowing :

φ = coefficient of adhesion.

$f' = a' - b'v_1$

The calculation is :

$m = f'$

$n = a' - b'v_1$

$$\left\{ \begin{array}{l} A = bQ' + nP' - \frac{ngI}{r^2} \\ B = aQ' - mP' + \frac{mgI}{r^2} + \frac{gI\sigma}{1000 r^2} \end{array} \right.$$

$$\left\{ \begin{array}{l} \lambda = \frac{gI}{r^2} \left(m + \frac{\rho}{1000} \right) \\ \lambda' = \frac{gIn}{r^2} \end{array} \right.$$

$$\left\{ \begin{array}{l} \alpha = \frac{gI}{r^2} \left(m + \frac{\rho}{1000} \right) \\ \beta = \lambda' \end{array} \right.$$

$$\left\{ \begin{array}{l} \gamma = \lambda + \frac{\lambda'B}{A} \end{array} \right.$$

$$\left\{ \begin{array}{l} \alpha = (A + \lambda') v_1 + \left(\lambda + \frac{\lambda'B}{A} \right) \log_n (B - Av_1) \\ \beta = \lambda' \end{array} \right.$$

$$\left\{ \begin{array}{l} \gamma = \lambda + \frac{\lambda'B}{A} \end{array} \right.$$

We find :

$$a) t_1 = \frac{I}{r^2 A} \log_n \frac{B}{B - Av_1}$$

$$b) v_2 = \left(1 + \frac{\lambda'}{A} \right) v_1 - \left(\lambda + \frac{\lambda'B}{A^2} \right) \log_n \frac{B}{B - Av_1}$$

$$c) l_1 = \frac{I}{r^2 A^2} \left[\left\{ \alpha - \frac{\beta B}{A} - \frac{\gamma}{2} \log_n \parallel \beta (B - Av_1) \parallel \right\} \log \frac{B}{B - Av_1} + \right.$$

NUMERICAL EXAMPLE.

Take an articulated railcar with 3 bogies having the following particulars :

Tare = 100 tonnes.

A constant braking effort $Q = 90$ % of the tare weight.

Duration of time during which pressure is admitted to brake cylinders to attain this braking effort = 2 seconds.

Frontal section = 10 square metres.

Coefficient of wind resistance at the given speed in metres per second = 0.07776.

Diameter of driving wheels = 1 metre.

Mass moment of inertia of a train of wheels = 20 kgr. $\times$ m. $\times$ sec².

Coefficient $\eta = 1.08$.

Consider the railcar travelling *empty on level track* at a speed of **94.302 km./h.**

(i.e. $\frac{94.302}{3.6} = 26.195$ metres per second)

at the beginning of brake application.

Taking specific rolling resistance as equal to 3 kgr. per tonne and coefficient of adhesion (considered constant) as equal to 0.18.

And finally, assuming the weight transmitted to the rails by a train of wheels to be 16 tonnes.

Under these conditions, we have :

$$P = 100.$$

$$K = \frac{Q}{P} = 0.9.$$

$$\alpha = 3.$$

$$\beta = 0.07776.$$

$$i = 0.$$

$$\varphi = 0.18$$

$$r = 0.50.$$

$$I = 20.$$

$$\eta = 1.08.$$

$$P' = 16000.$$

$$Q' = 16000 \times 0.9 = 14400.$$

Values of f and f' .

As the speed of the railcar at the moment of brake application is less than 100 km./h., we will take values for f and f' given by the formulae of M. DOYEN, viz. :

$$f = a - bv = 0.27 - 0.0072 v. \quad (1)$$

$$\left. \begin{aligned} f' &= a' - b'v = 0.095 - 0.0024 v, \\ \text{for } v &> 10 \text{ km./h.} \quad \dots \quad (2) \\ f' &= a' - b'v = 0.25 - 0.0504 v, \\ \text{for } v &< 10 \text{ km./h.} \quad \dots \quad (3) \end{aligned} \right\}$$

so that the speed corresponding to the transitional value $f' = (2)$ to that of $f' = (3)$ can be stated thus :

$$0.095 - 0.0024 v = 0.25 - 0.0504 v$$

from which :

$$v = 3.23 \text{ metres per second.}$$

In the text which follows, this speed will be referred to as the « transitional speed ».

Critical Speed.

The values of $\frac{\varphi}{K} = \frac{0.18}{0.9} = 0.20 < 0.27$ indicates conditions of skidding (i.e. locked wheels).

The value of the critical speed can be obtained :

$$\begin{aligned} v &= \frac{1}{b} \left(a - \frac{\varphi}{K} \right) \\ &= \frac{1}{0.0072} \left(0.27 - \frac{0.18}{0.9} \right) \\ &= 9.72 \text{ metres per second.} \end{aligned}$$

Other values.

v_1 metres per second = speed of vehicle at the moment of brake application = 26.195.

t_1 seconds = duration of period of brake cylinder operation = 2.

v_2 metres per second = speed of vehicle at the end of this time.

l_1 metres = distance travelled during this period.

v_3 metres per second = speed of the vehicle at the beginning of the transitional period between pure rolling and pure skidding = critical speed = 9.72.

t_2 seconds = duration of travel between the limits of speed v_2 and v_3 .

l_2 metres = distance travelled during this time.

v_4 metres per second = speed of the vehicle at the end of the transitory period mentioned above (beginning of the period of pure skidding).

t_3 seconds = duration of the said period.

l_3 metres = distance travelled during this period.

v_5 metres per second = transitory speed during the period of pure skidding = 3.23.

t_4 seconds = duration of travel between the limits of speed v_4 and v_5 .

l_4 metres = distance travelled during this time.

t_5 seconds = duration of travel between the limits of speed v_5 and stopping.

l_5 metres = distance travelled during this time.

Under these conditions :

1) Total time of travel of the vehicle from the moment of applying the brakes until the moment of stopping = $t_1 + t_2 + t_3 + t_4 + t_5$.

2) Corresponding distance travelled, or stopping distance = $l_1 + l_2 + l_3 + l_4 + l_5$.

3) The speeds v_1 and v_2 at the beginning and at the end of each of the pe-

riods mentioned above are given in the following table :

PÉRIODS			Speeds	
			v_1	v_2
I	Brake cylinder operation		v_1	v_2
II	Pure rolling		v_2	v_3
III	Transition		v_3	v_4
IV	Pure skidding	1st phase	v_4	v_5
		2nd phase	v_5	0

I. *Period of brake cylinder operation.*

v_1 = 26.195 metres per second.

$$f = a - bv_1 = 0.27 - 0.0072 \times 26.195 = 0.0814$$

$$\rho = \frac{100 \alpha + \beta S v_1^2}{100}$$

$$= \frac{(3 \times 100) + (0.07776 \times 10 \times 26.195^2)}{100}$$

$$= 8.33 \text{ kgr. per tonne.}$$

$$v_2 = v_1 - \frac{g}{\eta} \left(\frac{\pi}{4} f K + 0.001 \rho \right) t_1$$

$$= 26.195 - \frac{9.81}{1.08} \left(\frac{\pi}{4} \times 0.0814 \times 0.9 + 0.001 \times 8.33 \right) \times 2$$

$$= 25 \text{ metres per second.}$$

$$l_1 = v_1 t_1 - \frac{g}{\eta} \left(\frac{1}{2} f K + 0.0005 \rho \right) t_1^2$$

$$= 26.195 \times 2 - \frac{9.81}{1.08} \left(\frac{1}{2} \times 0.0814 \times \right.$$

$$\left. 0.9 + 0.0005 \times 8.33 \right) \times 2 \times 2 = 51.250 \text{ metres.}$$

II. *Period of pure rolling.*
(constant pressure).

$$\left\{ \begin{aligned} \gamma &= \frac{1000 P \gamma}{g \beta S} \\ &= \frac{1000 \times 100 \times 1.08}{9.81 \times 0.07776 \times 10} = 14157. \\ p &= \frac{1000 K b P}{\beta S} \\ &= \frac{1000 \times 0.9 \times 0.0072 \times 100}{0.07776 \times 10} = -833. \\ q &= \frac{(1000 K a + \alpha \pm i) P}{\beta S} \\ &= \frac{(1000 \times 0.9 \times 0.27 + 3) 100}{0.07776 \times 10} \\ &= 31635. \end{aligned} \right.$$

$$\left\{ \begin{aligned} \frac{p}{2} &= -416.5 \\ \frac{p^2}{4} &= 173472 \\ \frac{p^2}{4} - q &= 173472 - 31635 = 141837 \\ \Delta &= \sqrt{\frac{p^2}{4} - q} = \sqrt{141837} = 376.6. \\ A &= -\left(\Delta + \frac{p}{2}\right) = -(376.6 - 416.5) = 39.9 \\ B &= \Delta - \frac{p}{2} = 376.6 + 416.5 = 793.1. \\ v_2 &= 25 \\ v_3 &= 9.72 \\ A - v_2 &= 39.9 - 25 = 14.9 \\ A - v_3 &= 39.9 - 9.72 = 30.18 \\ B - v_2 &= 793.1 - 25 = 768.1 \\ B - v_3 &= 793.1 - 9.72 = 783.38. \end{aligned} \right.$$

$$\begin{aligned} t_2 &= \frac{\gamma}{2\Delta} \left\{ \log_n \frac{A - v_3}{A - v_2} - \log_n \frac{B - v_3}{B - v_2} \right\} \\ &= \frac{\gamma}{2\Delta} \times 2.303 \left\{ \log \frac{A - v_3}{A - v_2} - \log \frac{B - v_3}{B - v_2} \right\} \\ &= \frac{14157}{2 \times 376.6} \times 2.303 \left\{ \log \frac{30.18}{14.9} - \log \frac{783.38}{768.1} \right\} \\ &= \frac{14157 \times 2.303}{2 \times 376.6} \left\{ \log 2.0255 - \log 1.0199 \right\} \\ &= \frac{14157 \times 2.303}{2 \times 376.6} \left\{ 0.30653 - 0.00856 \right\} \\ &= \frac{14157 \times 2.303}{2 \times 376.6} \times 0.29797 \\ &= 12.88 \text{ seconds.} \\ l_2 &= \frac{\gamma}{2\Delta} \left\{ A \log_n \frac{A - v_3}{A - v_2} - B \log_n \frac{B - v_3}{B - v_2} \right\} \\ &= \frac{14157 \times 2.303}{2 \times 376.6} \left\{ 39.9 \times 0.30653 - 793.1 \times 0.00856 \right\} \end{aligned}$$

$$\begin{aligned}
 &= \frac{14157 \times 2.303}{2 \times 376.6} \left\{ 12.230 - 6.789 \right\} \left\{ \begin{aligned} bQ' &= 0.0072 \times 14400 = 103.7 \\ nP' &= 0.01114 \times 16000 = 178.2 \\ \frac{ngl}{r^2} &= 0.01114 \times 9.81 \times 80 = 8.7 \end{aligned} \right. \\
 &= \frac{14157 \times 2.303}{2 \times 376.6} \times 5.441 \\
 &= \mathbf{235.42 \text{ metres.}}
 \end{aligned}$$

III. *Period of transition between pure rolling and pure skidding.*

$$v_3 = 9.72 \text{ m./sec.}$$

For $v = v_3 = 9.72 \text{ m./sec.}$, we find :
 $f' = 0.095 - 0.0024 \times 9.72 = 0.0717.$

$$\text{From which : } \left\{ \begin{aligned} m &= f' = 0.0717 \\ n &= \frac{\varphi - f'}{v_3} = \frac{0.18 - 0.0717}{9.72} \\ &= \frac{0.1083}{9.72} = 0.01114 \end{aligned} \right.$$

$$A = bQ' + nP' - \frac{ngl}{r^2} = 273.2$$

$$aQ' = 0.27 \times 14400 = 3888$$

$$mP' = 0.0717 \times 16000 = 1147.2$$

$$\frac{mgI}{r^2} = 0.0717 \times 9.81 \times 80 = 56.3$$

$$\begin{aligned}
 \rho &= \frac{300 + (0.07776 \times 10 \times 9.72^2)}{100} \\
 &= \mathbf{3.735 \text{ kgr. per tonne.}}
 \end{aligned}$$

$$\frac{gI\rho}{1000r^2} = \frac{9.81 \times 80 \times 3.735}{1000} = 2.9$$

$$B = aQ' - mP' + \frac{mgI}{r^2} + \frac{gI\rho}{1000r^2} = 2800.$$

$$B - Av_3 = 2800 - 273.2 \times 9.72 = 144.4$$

$$\begin{aligned}
 t_3 &= \frac{I}{r^2 A} \log_n \frac{B}{B - Av_3} \\
 &= \frac{80}{273.2} \times 2.303 \times \log \frac{2800}{144.4} \\
 &= \frac{80 \times 2.303}{273.2} \times \log 19.4 \\
 &= \frac{80 \times 2.303}{273.2} \times 1.288 \\
 &= \mathbf{0.87 \text{ second.}}
 \end{aligned}$$

$$\left\{ \begin{aligned} \lambda &= \frac{gI}{r^2} \left(m + \frac{l}{1000} \right) = 9.81 \times 80 \left(0.0717 + \frac{3.735}{1000} \right) = 59.2. \\ \lambda' &= \frac{gIn}{r^2} = 8.7 \end{aligned} \right.$$

$$v_4 = \left(1 + \frac{\lambda'}{A} \right) v_3 - \left(\frac{\lambda}{A} + \frac{\lambda' B}{A^2} \right) \log_n \frac{B}{B - Av_3}$$

$$\begin{aligned}
&= \left(1 + \frac{8.7}{273.2}\right) 9.72 - \left(\frac{59.2}{273.2} + \frac{8.7 \times 2800}{273.2^2}\right) \log_n 19.4 \\
&= 10.03 - \frac{1}{273.2} \left(59.2 + \frac{8.7 \times 2800}{273.2}\right) 2.303 \times \log 19.4 \\
&= 10.03 - \frac{148.4 \times 2.303 \times 1.288}{273.2} \\
&= 10.03 - 1.61 \\
&= 8.42 \text{ metres per second.}
\end{aligned}$$

$$\begin{aligned}
\alpha &= (A + \lambda') v_3 + \left(\lambda + \frac{\lambda' B}{A}\right) \log_n (B - A v_3) \\
&= (273.2 + 8.7) 9.72 + \left\{59.2 + \frac{8.7 \times 2800}{273.2}\right\} \log_n 144.4 \\
&= 281.9 \times 9.72 + 148.4 \times \log_n 144.4 \\
&= 2740 + 148.4 \times 2.303 \log 144.4 \\
&= 2740 + 148.4 \times 2.303 \times 2.159 \\
&= 2740 + 738 \\
&= 3478
\end{aligned}$$

$$\beta = \lambda' = 8.7$$

$$\gamma = \lambda + \frac{\lambda' B}{A} = 148.4$$

$$l_3 = \frac{1}{r^2 A^2} \left\{ \left[\alpha - \frac{\beta B}{A} - \frac{\gamma}{2} \log_n \{B (B - A v_3)\} \right] \log_n \frac{B}{B - A v_1} + \beta v_3 \right\}$$

$$\frac{1}{r^2 A^2} = \frac{80}{273.2^2}$$

$$\alpha = 3478$$

$$\frac{\beta B}{A} = \frac{8.7 \times 2800}{273.2} = 89.2$$

$$\begin{aligned}
\frac{\gamma}{2} \log_n \{B (B - A v_3)\} &= \frac{148.4}{2} \times 2.303 \log \{2800 \times 144.4\} \\
&= \frac{148.4 \times 2.303 \times 5.607}{2} \\
&= 957
\end{aligned}$$

$$\begin{aligned}\log_n \frac{B}{B - Av_3} &= 2.303 \log \frac{B}{B - Av_3} = 2.303 \times \log \frac{2800}{144.4} \\ &= 2.303 \times \log 19.4 \\ &= 2.303 \times 1.288\end{aligned}$$

$$\beta v_3 = 8.7 \times 9.72 = 84.5$$

$$\begin{aligned}l_3 &= \frac{80}{273.2^2} \left\{ [3478 - 89.2 - 957] 2.303 \times 1.288 + 84.5 \right\} \\ &= \frac{80}{273.2^2} \left\{ 2431.8 \times 2.303 \times 1.288 + 84.5 \right\} \\ &= \frac{80}{273.2^2} \left\{ 7214 + 84.5 \right\} \\ &= \frac{80 \times 7298.5}{273.2^2} \\ &= 7.83 \text{ metres.}\end{aligned}$$

IV. Period of pure skidding (wheels locked).

First phase.

$$\left\{ \begin{aligned}f' &= a' - b'v = 0.095 - 0.0024 v \\ v_4 &= 8.42 \\ v_5 &= 3.23\end{aligned}\right.$$

$$\left\{ \begin{aligned}\gamma &= \frac{1000 P}{g\beta S} = \frac{1000 \times 100}{9.81 \times 0.07776 \times 10} = 13109 \\ p &= - \frac{1000 b'P}{\beta S} = - \frac{1000 \times 0.0024 \times 100}{0.07776 \times 10} = - 308.6 \\ q &= \frac{(1000 a' \pm i) P}{\beta S} = \frac{1000 \times 0.095 \times 100}{0.07776 \times 10} = 12217 \\ \frac{p}{2} &= - 154.3 \\ \frac{p^2}{4} &= 23815 \\ \frac{p^2}{4} - q &= 23815 - 12217 = 11598 \\ \Delta &= \sqrt{\frac{p^2}{4} - q} = \sqrt{11598} = 107.7\end{aligned}\right.$$

$$\begin{cases} A = -\left(\Delta + \frac{p}{2}\right) = -(107.7 + 154.3) = 46.6. \\ B = \Delta - \frac{p}{2} = 107.7 + 154.3 = 262. \end{cases}$$

$$\begin{aligned} t_4 &= \frac{\gamma}{2\Delta} \left\{ \log_n \frac{A - v_5}{A - v_4} - \log_n \frac{B - v_5}{B - v_4} \right\} \\ &= \frac{\gamma}{2\Delta} \times 2.303 \times \left\{ \log \frac{A - v_5}{A - v_4} - \log \frac{B - v_5}{B - v_4} \right\} \\ &= \frac{\gamma}{2\Delta} \times 2.303 \times \left\{ \log \frac{43.37}{38.18} - \log \frac{258.77}{253.58} \right\} \\ &= \frac{\gamma}{2\Delta} \times 2.303 \times \{ \log 1.13593 - \log 1.02050 \} \\ &= \frac{\gamma}{2\Delta} \times 2.303 \times \{ 0.05535 - 0.00881 \} \\ &= \frac{13109 \times 2.303 \times 0.04654}{2 \times 107.7} \\ &= 6.51 \text{ seconds.} \end{aligned}$$

$$\begin{aligned} l_4 &= \frac{\gamma}{2\Delta} \left\{ A \log_n \frac{A - v_5}{A - v_4} - B \log_n \frac{B - v_5}{B - v_4} \right\} \\ &= \frac{\gamma}{2\Delta} \times 2.303 \times \left\{ A \log \frac{A - v_5}{A - v_4} - B \log \frac{B - v_5}{B - v_4} \right\} \\ &= \frac{\gamma}{2\Delta} \times 2.303 \times \{ 46.6 \times 0.05535 - 262 \times 0.00881 \} \\ &= \frac{\gamma}{2\Delta} \times 2.303 \times \{ 2.5793 - 2.3082 \} \\ &= \frac{13109 \times 2.303 \times 0.271}{2 \times 107.7} \\ &= 37.980 \text{ metres.} \end{aligned}$$

Second phase.

$$\begin{cases} f' = a' - b'v = 0.25 - 0.0504 v \\ v_5 = 3.23. \end{cases}$$

$$\begin{aligned} t_5 &= \frac{1}{gb'} \log_n \frac{a'}{a' - b'v_5} \\ &= \frac{1}{gb'} \times 2.303 \times \log \frac{0.25}{0.25 - 0.0504 \times 3.23} \end{aligned}$$

$$\begin{aligned}
 &= \frac{2.303}{gb'} \times \log 2.867 \\
 &= \frac{2.303 \times 0.4574}{9.81 \times 0.0504} \\
 &= 2.13 \text{ seconds} \\
 l_5 &= \frac{1}{b'} \left(a't_5 - \frac{v_5}{g} \right)
 \end{aligned}$$

$$\begin{aligned}
 &= \frac{1}{0.0504} \left(0.25 \times 2.13 - \frac{3.23}{9.81} \right) \\
 &= \frac{1}{0.0504} (0.5325 - 0.3293) \\
 &= \frac{0.2032}{0.0504} \\
 &= 4.030 \text{ metres.}
 \end{aligned}$$

SUMMARY

Periods.	Speed in metres per second	Time in seconds	Distance travelled in metres
	$v_1 = 26.195$		
1st period		$t_1 = 2. —$	$l_1 = 51.250$
	$v_2 = 25. —$		
2nd period		$t_2 = 12.88$	$l_2 = 235.420$
	$v_3 = 9.72$		
3rd period		$t_3 = 0.87$	$l_3 = 7.830$
	$v_4 = 8.42$		
4th period	1st phase	$t_4 = 6.51$	$l_4 = 37.980$
	2nd phase $v_5 = 3.23$		
		$t_5 = 2.13$	$l_5 = 4.030$
	$v_6 = 0$		
TOTALS		$t = 24 \ 39$	$l = 336.510$

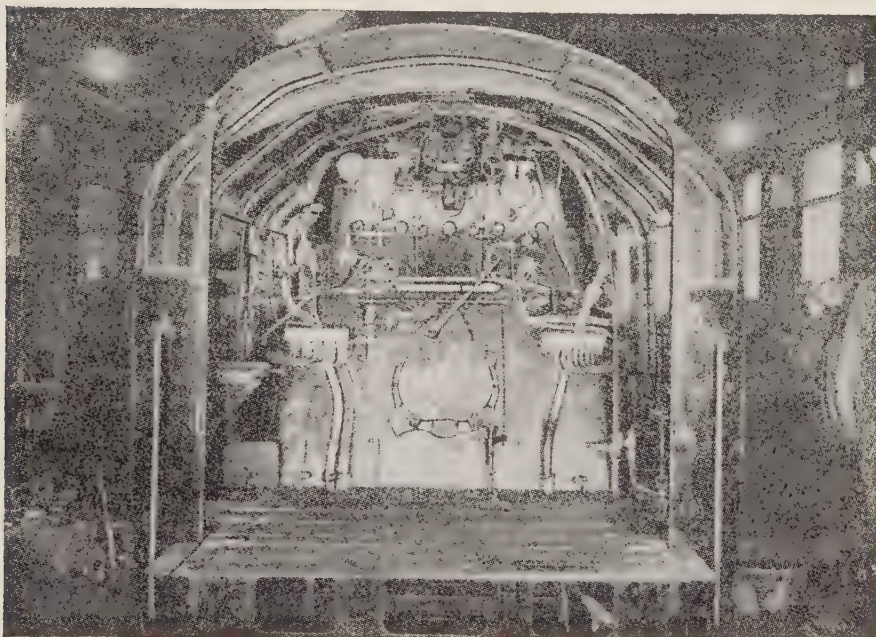
Pacific locomotives on the Southern Railway,

by O. V. S. BULLEID,

M. I. Mech. E., Chief Mechanical Engineer, Southern Railway.

(*Modern Transport.*)

(concluded.)*



View of footplate layout and cab fittings on Southern Railway Pacific of the Merchant Navy class.

IV. — Cab fittings and accessories.

Trouble from smoke and vapour beating down, with the original form of front end, was attributed to eddy currents, set up by the passage of the smokebox through the air, fanning out sideways, and setting up a pocket of low pressure along the side of the barrel behind the chimney centre line, into which

the steam and smoke are drawn down. The more efficient the exhaust design, especially at early cut-offs and low steam-chest pressures, the worse the trouble, as there is less energy left in the exhaust to carry the steam and smoke away. Under certain weather conditions drivers experienced difficulty in observing the signals with the original

(*) Previous portions were published in the June 1946 number of the *Bulletin*.

front end. This led to a series of experiments on models in the wind tunnel at Southampton University, followed by tests in service, and the form of hood over the front of the smoke-box, illustrated in *Modern Transport* of May 4 (see also the *Bulletin*, June 1946 number, p. 115), was finally adopted for the Merchant Navy and West Country classes. The author wishes to acknowledge the help of Wing Commander T. R. Cave-Brown-Cave in finding this neat solution. Cab fittings have been grouped for accessibility and not for symmetry. On the driver's side are the regulator, reverser, brake valve, blower, sand valve, steamchest pressure gauge, one water gauge, oil pressure gauges and cylinder cock gear. On the fireman's side are two injectors, with the water and steam control valves on the cab side, dampers, boiler pressure gauge, steam-heating stopcock and pressure gauge, watering pipe, one water gauge, electric generator steam valve, firedoor treadle and hand control lever. Troughs along the tender sides facilitate outlook when running backwards. The engines are fitted with a generator set driven by a $\frac{3}{4}$ h.p. steam turbine running at 4 000 r. p. m. and rated at 350-500 watts.

Balancing.

In these engines the reciprocating parts have been made as light as possible and are not balanced. The rotating masses, on the other hand, are balanced completely in the wheels. The crank axle is built up, but the crank webs are not extended as has been usual in recent practice. The result was to save dead weight, as the extended web would have weighed 490 lb. per web, whereas only 548 lb. were needed for balancing in the wheels, a saving of 432 lb. The fact that the reciprocating parts have not been balanced has not been attended by any

ill-effects, and there is no indication in the riding of the engine that these parts are not counterbalanced. Tests over Barnes Bridge at 78 m. p. h. showed the complete absence of disturbing forces at the rail.

The gauge faces in the cab are black, with luminous figures. These are illuminated by a lamp in the cab roof enclosed in a box fitted with a glass which only allows ultra-violet rays to pass through, so that there is no visible light from it. The gauges can be clearly read at night and when running into a tunnel during the day. The water in the gauge glass is illuminated by a narrow band of light directed at the water columns through a slit in the fitting. A light controlled by the fireman is fitted below the footplate to light the injector overflow at night. The headlamps are electrically lighted and inspection lights are provided to facilitate examination of the running gear.

Tender tanks.

The tender tanks are fabricated, the tank plates being 3-16 in. thick. Additional water filling holes have been provided at the leading end of the tender at both sides, so that the fireman can fill up without climbing to the top of the tender; they also enable the water level to be checked easily. The weight of the tenders empty is 20 tons 10 cwt. The capacity is 5 tons of coal and 5 000 gallons of water.

The author wishes to acknowledge the encouragement he has received from his general manager, Sir Eustace Missenden, and the help given by his assistants, draughtsmen, works managers, foremen and men in designing and building, and running shed staffs and enginemen for the way they have looked after and handled them.

An improved form of railjoint.

The Ellson joint.

Securing smooth running.

(Modern Transport.)

The question of obtaining satisfactory joints in railway tracks has been a problem to permanent way engineers from the earliest days, and these difficulties are enhanced by the need to provide a smooth roadbed for heavy locomotives and rolling stock operating at increasingly high average speeds over either main or secondary lines. Various forms of scarfed joint supported on a single sleeper in a joint-chair were a favourite device, as seen in rails laid well over a century ago at Hetton colliery and as described in the celebrated Losh and Stephenson patent. The need for provision of an expansion gap brought adherence to the square joint, however, as George Stephenson himself admitted. The brilliant Bridges Adams, who has to his credit so many other features of the modern railway, in 1847 introduced the suspended joint and fishplate in lieu of the joint-chair and this rapidly became the standard British arrangement, especially following its adoption by the London and North Western Railway in 1853.

Under the weight of a moving vehicle, the rails are deflected; an upwards and downwards wave motion taking place in the track. But at joints this regular motion is interrupted if the joint has not the same strength, considered as a girder, as the remainder of the rails it connects. As the load passes over, the fishplate, even before the smallest wear of the fishing surfaces takes place, al-

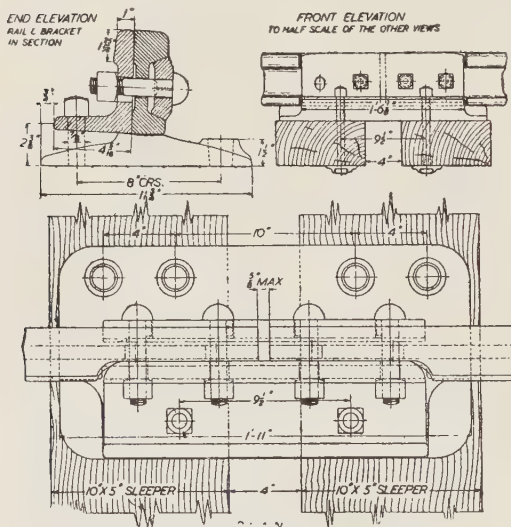
lows the end of the trailing rail to deflect before the wheel strikes the leading end of the succeeding rail, and no matter how small this deflection is, the impact and sudden lift sets up jolting in the vehicles. As the motion continues with successive trains, the wear on the fishplate grows, and this leads to progressively heavier blows from the wheels, resulting in battering of the rail ends, breakage of fishplates, wear and tear on the rolling stock and increasing noise. Special joint chairs, and wider sleepers at joints (12 in. instead of 10 in.), are employed by some railways; the sleepers may be placed closer together at joints; and packing is carefully done as necessary at the joint. Liners and shims are also employed to take up appreciable wear on fishplates, and so to endeavour to limit deflection. Of recent years, two-bolt fish plates, 9- or 11-in. long in place of the 18-in. long four-bolt fishplates, have been used to facilitate closer spacing of sleepers at joints, and to give better support to the track. Nevertheless, the joint remains the weakest point in the track, and increasingly so as loads and speeds mount higher.

Earlier attempts.

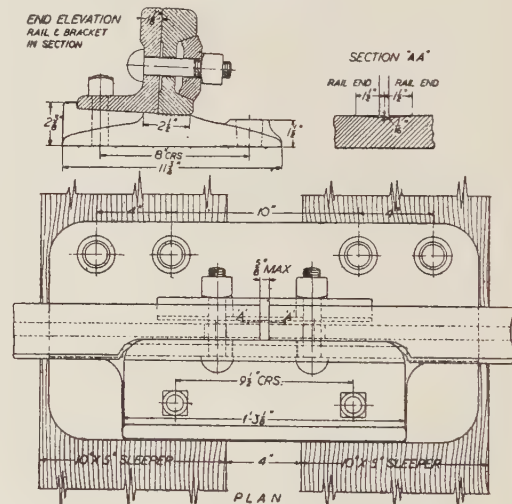
Numerous endeavours have been made to design a railjoint which would stand up to requirements in a more satisfactory manner, but be simple to ma-

ke, fit and maintain. Before welding of tramtrack became generally accepted, tramway engineers were especially prolific in producing « supported », or « held-down » railjoint on various types of support, usually difficult to manufacture or adjust. In the Dicker joint, the patentee tried to overcome the reversal of strains on the ordinary fishplate, by a six-bolt fishplate. The out-

that of Mr. George Ellson, C. B. E., consulting civil engineer, Southern Railway, the patentee, for permission to use the original drawings from which these were prepared, and to quote details of the joint and of the tests made with it upon the Southern Railway. We have travelled over several sections of track laid with Ellson joints, and have been most favourably impressed by the increased



Four-bolt Ellson railjoint in elevation and plan.



Two-bolt Ellson joint carried on two sleepers.

side member extended upwards to the level of the rail tables, which were recessed by the joint to accommodate it. On curved rail this joint was not suitable for resisting twisting strains, however.

We illustrate in the accompanying drawings and photographs, a successful effort to overcome the railjoint difficulty, in the shape of the Ellson joint. We are indebted to the courtesy of Mr. V. A. M. Robertson, C. B. E., M. C., chief civil engineer, Southern Railway, and to

riding comfort in the train and the reduction of noise.

The principle underlying the design of the Ellson joint, is to maintain, as nearly as possible, continuous support of wheels across the rail gap, by means of the bracket, or cleat, on the outside of the rail, and the ordinary fishplate on the inside. The bracket, or cleat, it will be observed from the illustrations, is recessed into the rails at the ends, and carries the load of the wheel tread as it passes over the joint. Normally,

the load is distributed to the two sleepers nearest the joint, through the baseplate, cast in one piece, thus ensuring that the bearing surfaces of these sleepers are in one plane. It has, however, been found by experience that the vertical stiffness of the bracket is such that the continuity of the baseplate is not essential. Up to the present, two types have been mainly used, one with four bolts and the bracket 18-in. long, and one with two bolts and the bracket 15-

6 000 joints, and by the end of this year 50 miles will be in use. The recessing of the ends of the rails was done at first with shaping machines, but is now effected by female labour, using precision flame cutting oxy-acetylene burners. Tests at the National Physical Laboratory, Teddington, were carried out and confirmed that such a process did not reduce the fatigue strength of the rail. The brackets are cut from a specially rolled section of rail steel quality, the



Four-bolt Ellson railjoint with 18-in. bracket, and (right) two-bolt 15-in. bracket type.

in. long. Experiments have also been made with brackets 12-in. long, and also with the joint supported on one sleeper only. This latter is a modern reversion to something resembling the joint chair, with a very great improvement in mechanical strength, and is only possible by reason of the effective bridging of the gap by the bracket, ensuring continuity of the bearing surface for the wheel, thus eliminating impact.

The first length of line, a mile long, using four-bolt brackets, was laid in March, 1940, in the down fast electric line near Gatwick, on the London-Brighton route, and in the same year, a length, a mile and a half long, was laid in the down line of the Dover boat-train route near Marden, which is worked under steam conditions by the heaviest and fastest engines. Since then, a further 40 miles have been laid, involving about

object being, to obtain the same rate of wear in the bracket as in the rail, and this is accomplished.

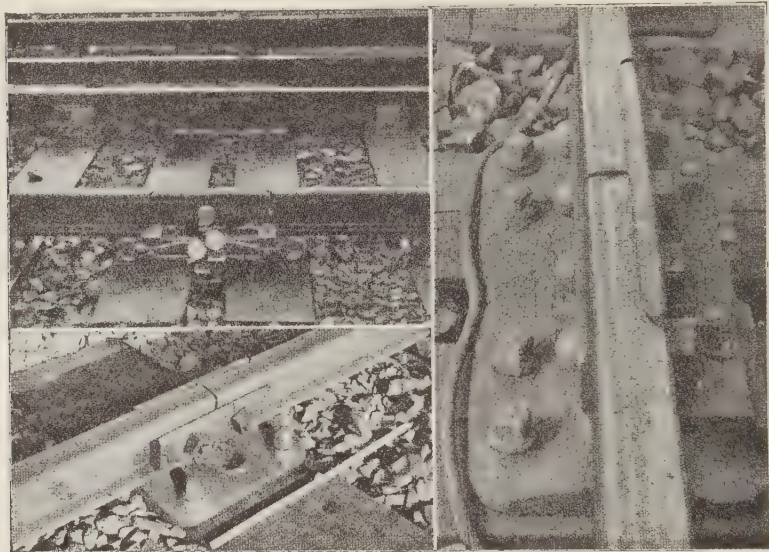
Improved running.

With these joints a marked reduction in the noise of running is achieved and less attention is required in the packing of the sleepers supporting the joints. Riding is improved, as is shown by tests with dial deflectometers at Coulsdon in January, 1943, when the passage of a locomotive over various types of joint was found to give a mean upwards and downwards range of deflection of the rail of seven-thousandths of an inch on the Ellson joint, compared with eleven-thousandths for the two-bolt standard joint, and twenty-three-thousandths for the four-bolt standard joint. The deflection of the bracket was one-thou-

sandth of an inch. These results confirm that the bracket acts as a bridge over the joint, and greatly reduces the relative movement between the ends of the rails under traffic.

This is confirmed by the visual indi-

ted, and it is anticipated that the premature renewal of rails from this cause will be avoided. The joint is equally adapted for use with flat-bottom rails, and experiments are now in progress on such tracks on the Great Indian Penin-



Ellson railjoint under observation at Coulsdon, showing measuring instruments; below, 12-in. two-bolt cleat experimentally carried on one sleeper; right, plan view of Ellson four-bolt railjoint.

cation of the wear on the top of the bracket. Where welded rails up to 180 ft. long are used, the joint solves the problem of spanning satisfactorily the longer gap required for expansion purposes, it being only necessary suitably to slot the fishbolt holes. Battering and crippling of the rail-ends is also preven-

sula and London Midland and Scottish Railways. Permanent way engineers and others concerned with the divergent requirements of more economical track and rolling stock maintenance, and higher speed train operation, will follow the development of the use of the Ellson railjoint with close interest.

Comparative stresses in vertical and canted rails.

An examination of the difference in resultant stresses and pressures between rails laid vertically and those canted at the usual 1 in 20 angle,

by R. A. INGLIS, A. M. Inst. C. E.

(*The Railway Gazette.*)

In the following analysis and comparison of the stresses in rails laid either vertically or canted at the usual angle of 1 in 20, the writer does not intend to enter into the pros and cons of the two practices, but merely to examine the difference in the resulting stresses and pressures. The method employed is the usual graphical (graphic statics) one for any horizontal girder subjected to purely transverse loading. The two general cases of rails in straight track or tangent, and curved track will be considered independently.

Case I. — Straight track.

The accompanying diagram « A » shows a 100-lb. B. E. (R) flat bottom rail section, with the wheel tread and flange in its normal position for straight track. Full lines apply to canted rail, dotted lines to vertical. In order to facilitate comparison between vertical and canted rail, the wheel tread is canted relative to the rail in the latter case. The momental ellipse has been drawn (one half only) with major and minor semi-axis equal to the two swing radii $k_x = 2.21$ in. and $k_y = 1.02$ in. as shown. The planes of loading and bending in both cases are indicated, also the neutral axis. As is well known, the neutral axis is conjugate to the plane of loading and the plane of bending is at right angles to the plane of the neutral axis. The

graphical construction will not be described here, but in the case of the canted rail, the angle θ' , which the neutral axis makes with the principal y axis of the rail, can be found or checked by means of the following equation :

$\tan \theta \times \tan \theta' = \frac{k_y^2}{k_x^2}$ where $\tan \theta$ is the tangent of the angle which the plane of loading makes with the y axis.

In this case $\tan \theta = \frac{1}{20} = 0.05$

$$\therefore \tan \theta' = \frac{1.02^2}{2.21^2 \times 0.05} = 4.26035$$

and $\theta' = 76.47' 26''$, as drawn.

Since the loading is purely transverse, the neutral axis xx (rail vertical) or zz (rail canted) will pass through the centroid C of the section as shown. For canted rail, the tangent point P between the wheel tread and the rail head coincides with the centre of the rail head, and the height of the rail being 6 in. the line of action of the wheel load W, which is parallel to the plane of loading, meets the rail base at a point $6/20 = 0.3$ in. inside of its centre. For vertical rail, since the radius of the head is 9 in., the tangent point P' is 0.45 in. inside the centre, and the load W intersects the base at a point vertically beneath P'.

The maximum tensile and compressive stresses in the rail section vary directly as the distance y of the extreme

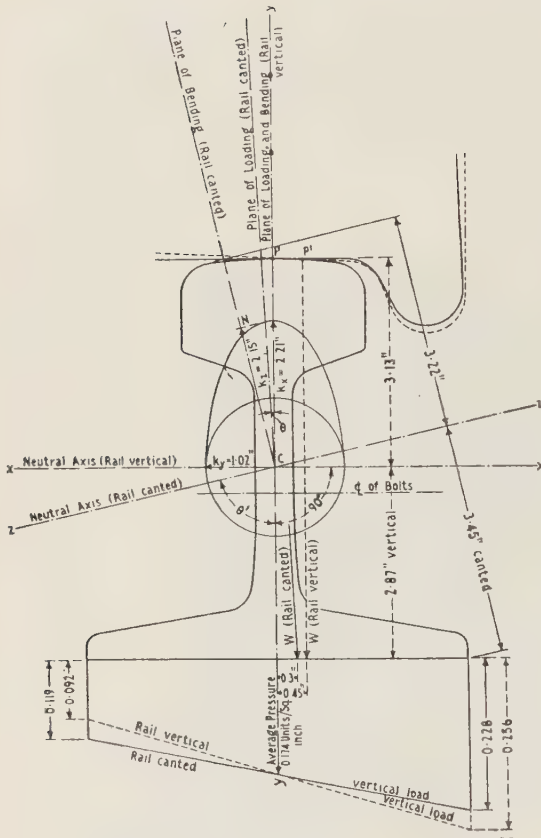
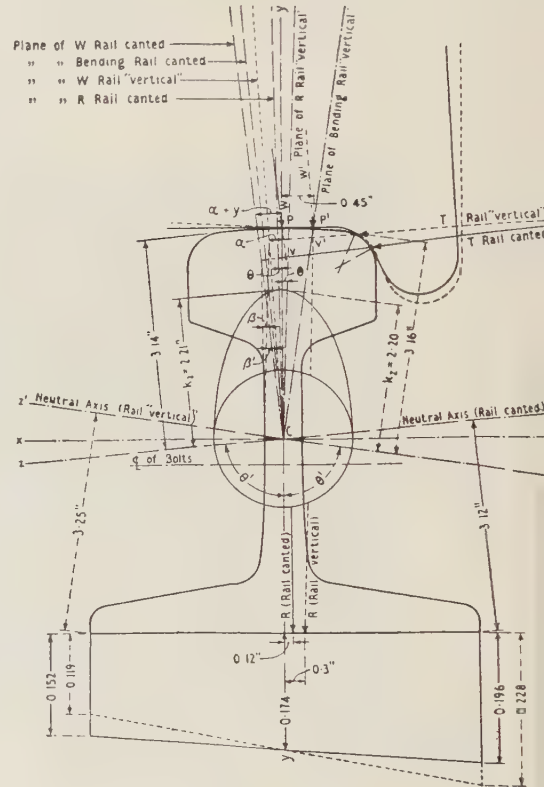


Diagram of Unit Pressures under base of rail for unit wheel load per unit length of rail.

A — TANGENT.



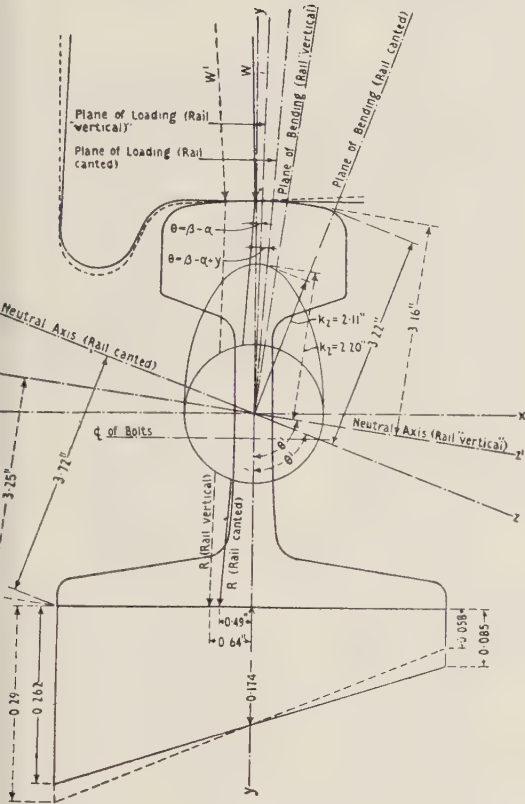
B — CURVE. OUTER RAIL.

fibres from the neutral axis, and inversely as the square of the swing radius about the neutral axis. The distances from the neutral axis to the extreme tension and compression fibres are shown in both cases. By the properties of the momental ellipse, it can be shown that the swing radius k_c for the canted rail = CN, where CN is the perpendicular from the centroid C upon the tangent to the ellipse drawn parallel to the neutral axis zz (see diagram). In this case CN is found to be

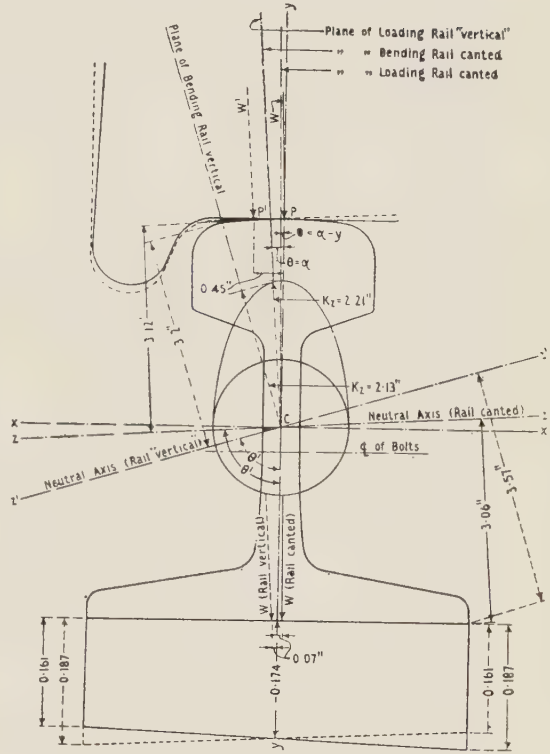
2.15 in. Therefore the ratio of the maximum tensile stress in the canted rail to that in the vertical rail equals :

$$\frac{3.45}{2.15^2} \times \frac{2.21^2}{2.87} = 1.27, \text{ i.e., the maximum tensile stress in the canted rail is about 27 per cent. more than its value for vertical rail. Similarly the maximum compressive stress in the canted rail is :—}$$

$$\left(\frac{3.22}{2.15^2} \times \frac{2.21^2}{3.13} - 1 \right) 100 = \text{about 9 per}$$



C — CURVE, INNER RAIL.



D — CURVE, INNER RAIL.
Vehicle at rest or moving dead slow.

cent. more than it is in the vertical rail. The maximum tensile stress in the canted rail occurs at the inside corner of the foot and the maximum compressive stress at the outside edge of the head. In the vertical rail the maximum tensile stress occurs at all points in the rail base, and the maximum compressive stress at the centre P of the running surface.

Since the width of the foot is $5\frac{3}{4}$ in., the average pressure over the base is 0.174 units per sq. in. for unit wheel load per unit length of rail ($W = 1$). Maximum and minimum unit pressures

for both vertical and canted rail are shown as calculated by means of the usual formula :

$$p = \frac{W}{B} \left(1 \pm \frac{6e}{B} \right).$$

where e denotes the eccentricity of W and $B = 5\frac{3}{4}$ in. It will be observed that vertical rail gives a maximum pressure (at the inside edge) 12 per cent. greater than that for canted rail.

Since stresses are of more practical importance than pressures, the advantage lies with the vertical rail from the

aspect of rail stress alone as is only to be expected.

Note. — Diagram « A » can of course be used to find the actual unit stress at any point in the rail section caused by any given bending moment M at that section, for the stress $f = \frac{M}{A} \times \frac{y}{k^2}$, where A is the cross sectional area of the rail.

Similarly the actual unit pressure at any point in the base can be found by multiplying the corresponding unit pressure taken from the diagram by the actual load per inch length of rail.

Case II. — Curved track, outer rail.

Diagram « B » illustrates the case of horizontal flange thrust on the outer rail due to centrifugal force on curves. It will be realised that in the case of rail in curves all planes, stresses, and pressures vary with the radius, superelevation, and speed. For the sake of example, the thrust T has been calculated for unit wheel load W per unit length of rail on a curve of 300 m. radius at a speed of 60 k.p.h. and equals 0.094 units. Since T varies directly as the square of the speed, and inversely as the radius, the unit value of T can readily be found for any other curve and speed. Once the point of application and direction of the wheel load W and the thrust T , have been found, the two combined give the direction and the point of application of the resultant pressure R on the base, which in the case of rail normal to sleeper (« Vertical rail ») falls 0.3 in., and for canted rail 0.12 in., to the inside of the centre of the foot as shown, the points of application of W being P and P' , as before. V and V' are the points of intersection of the line of action of T with W and W' respectively.

The angles which the planes of loading and of the neutral axis make with the y axis of the rail, are found as follows :—

Let α denote the angle of superelevation, and suppose the rail is laid vertical to the sleeper. Then if β denotes the angle which the plane of loading R makes with W , $\tan \beta = \frac{T}{W} = 0.09438$, and the angle which the plane of loading R makes with the y axis of the rail section is $\theta = \beta - \alpha$.

For 300 m. radius, and 60 k.p.h., the superelevation is 11 cms., and the gauge is widened to 1.682. The width of the rail head is, say, 7 cms. Therefore :

$$\sin \alpha = \frac{11}{175} \text{ and } \tan \alpha = 0.06288, \text{ or } \alpha = 3.35' 54''.$$

$$\beta = 5.23' 30'', \text{ therefore } \theta = 1.47' 36'', \tan \theta = 0.03131.$$

$$\text{Therefore } \tan \theta = \frac{1.02^2}{2.21^2 \times 0.03131} = 6.804 \text{ or } \theta' = 81.38' 34'' \text{ as drawn, the plane of loading } R \text{ being to the right of the } y \text{ axis.}$$

If the rail is laid canted, and γ denotes the angle of cant, $\theta = \beta - \alpha - \gamma$. $\tan \gamma = 0.05$, or $\gamma = 2.51' 46''$, β and α have the same values as before, therefore :

$$\theta = -1.04' 10'', \text{ and } \tan \theta = 0.01867$$

$$\tan \theta' = \frac{1.02^2}{2.21^2 \times 0.01867} = 11.4116 \text{ or } \theta' = -84.58' 29''$$

as drawn, the minus sign indicating that the plane of loading R is to the left of the y axis. For this case, k_z for canted rail = 2.21 in., and for vertical rail = 2.20 in., as shown. Having measured the distances y we have :

Max. tensile stress in the canted rail

$$\left(1 - \frac{3.12}{2.21^2} \times \frac{2.20^2}{3.27}\right) \times 100, \text{ which is}$$

5 per cent. less than its value for vertical rail, and the maximum compressive stress in the canted rail =

$$\left(1 - \frac{3.14}{2.21^2} \times \frac{2.20^2}{3.15}\right) \times 100, \text{ which is}$$

1.2 per cent. less than its value for vertical rail.

The difference in stress is much smaller than for straight track, but it should be noted that in that case the canted rail is stressed more than the vertical rail.

The calculated maximum and minimum unit pressures in the two cases are as indicated in the diagram, from which we obtain the following result:—

The maximum pressure for the vertical rail is 16 per cent. more than that for the canted rail. This is similar in kind to the result reached in the case of straight track.

Case III. — Curved track, inner rail.

(See diagram C.)

The points of application of W are the same as before. W and W' combined with T = 0.094 W give the direction of the resultant force on the rail R (and R'), and its eccentricity at the base of the rail.

θ for the canted rail = $\beta - \alpha + \gamma$ = 4.39' 22'', and $\tan \theta = 0.08145$. There-

fore $\tan \theta' = \frac{1.02^2}{2.21^2 \times 0.08145} = 2.61531$, or $\theta' = 69.04' 30''$. For the « vertical » rail, $\theta = \beta - \alpha = 1.47' 36''$, as for the outer rail, and in this case $\theta' = 81.38' 34''$, as before.

The swing radius $k_z = 2.11$ in. and $k_z' = 2.20$ in. Having measured the various distances y from the neutral axis

to the extreme fibres in each case, we have :

Maximum tensile stress in the canted rail is greater than that in the « vertical » rail by 100 $\left(\frac{3.72}{2.11^2} \times \frac{2.20^2}{3.25} - 1 \right)$ = 13 per cent.

Maximum compressive stress in the canted rail is 100 $\left(\frac{3.22}{2.11^2} \times \frac{2.20^2}{3.16} - 1 \right)$ = 10.1 per cent. more than that in the « vertical » rail.

The maximum and minimum pressures may be compared as before. It will be noted that the eccentricity of R for the canted rail is about four times greater than the eccentricity in the outer rail, and for the « vertical » rail the eccentricity is twice that in the outer rail. There is, therefore, a greater variation in pressure between the inner and outer edges of the rail base, and the maximum pressure in the inner rail, is about 27 per cent. greater than that in the outer rail when the rail is « vertical », and about 34 per cent. greater when the rail is canted. This deduction, of course, assumes that the wheel load on each rail is the same, i.e., that the superelevation is correct for the speed. If the superelevation is more than the speed warrants, then the inner rail will take a greater proportion of the axle load than the outer rail.

Similarly, no comparison of the stresses in the inner and outer rails can be made unless the bending moment in each rail is the same.

Case IV. — Curved track, inner rail.

Vehicle at rest or moving dead slow, see diagram D. In this case there is no centrifugal force, otherwise the conditions are the same as for case III.

For the canted rail the angle θ which the plane of loading makes with the y axis is equal to $\alpha - \gamma = 0^\circ 44' 08''$, $\tan \theta = 0.01284$.

$$\therefore \tan \theta' = \frac{1.02^2}{2.21^2 \times 0.01284} = 16.59098 \text{ or } \theta' = 86^\circ 33' 02''.$$

For the vertical rail, the angle which the plane of loading makes with the axis y is equal to $\alpha = 3^\circ 35' 54''$ $\tan \alpha = 0.06288$.

$$\therefore \tan \theta' = \frac{1.02^2}{2.21^2 \times 0.06288} = 3.38768, \text{ or } \theta' = 73^\circ 33' 15'', \text{ as drawn in the diagram.}$$

k_z for the canted rail is 2.21 in. and for the vertical rail 2.13 in. Measuring the distances from the neutral axis to

the extreme fibres in each case, we have :

Maximum tensile stress in the canted rail is $\left(1 - \frac{3.06}{2.21^2} \times \frac{2.13^2}{3.57}\right) 100$, say 18 per cent. less than in the vertical rail.

Maximum compressive stress in the canted rail is $\left(1 - \frac{3.12}{2.21^2} \times \frac{2.12^2}{3.2}\right) 100 = 9$ per cent. less than its value for the vertical rail.

Owing to the eccentricity of the load W on the rail base being the same (0.07 in.) in both cases, but on opposite sides of the centre, the maximum and minimum unit pressures on the base have the same values, but in the canted rail the maximum pressure is at the outer edge, while in the vertical rail, the maximum pressure is at the inner edge.

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PANCHAUD (F.). — Quelques aspects du calcul des ouvrages en béton précontraint. (6 000 mots & fig.)

1944 **691**
Bull. techn. de la Suisse romande, n° 2, 22 janvier, p. 13.
BOLOMEY (J.). — Choix des caractéristiques et contrôle du béton sur les chantiers. (8 000 mots & fig.)

1944 **621 .431 .72 (.494)**
Bull. techn. de la Suisse romande, n° 7, 1^{er} avril, p. 81.
MEYER (A.). — Les automotrices Diesel-mécaniques de 300 ch. du Chemin de fer central thurgovien. (3 500 mots, 1 tableau & fig.)

Economie et Technique des Transports.
(Lucerne.)

1946 **625 .5**
Economie et technique des transports, fasc. 55/56, mars-avril, p. 30.
CARLEVARO (U.). — Rupture d'un câble porteur de téléphérique. (1 200 mots & fig.)

1946 **625 .5 (.44)**
Economie et technique des transports, fasc. 55/56, mars-avril, p. 34.
HUG (Ad.-M.). — Téléphériques de l'Aiguille du Midi (Massif du Mont-Blanc). (1 200 mots & fig.)

1946 **625 .2**
Economie et technique des transports, fasc. 55/56, mars-avril, p. 38.
FOBELETS (P.). — View on transposition of materials for lightweight construction of vehicles. (1 000 mots.)

Génie Civil. (Paris.)

1941 **624 .63 (.44)**
Génie Civil, n° 3053-3054, 16-23 août, p. 77.
LOSSIER (H.). — La **reconstruction du pont** de Pouilly-sous-Charlieu, sur la Loire. (2 200 mots & fig.)

1941 **621 .392 (.44) & 624 .62 (.44)**
Génie Civil, n° 3055-3056, 30 août-6 septembre, p. 89.
FAUCONNIER. — Le **renforcement par soudure à l'arc électrique** du pont d'Austerlitz, sur la Seine, à Paris. (4 500 mots & fig.)

1941 **62. (01**
Génie Civil, n° 3055-3056, 30 août-6 septembre, p. 93.
BOUTARIC (A.). — L'état actuel de la **photoélasticité**, (10 000 mots.)

1941 **624 .63 (.44)**
Génie Civil, n° 3057-3058, 13-20 septembre, p. 109.
DEUTSCH (C.). — Le **nouveau pont** du Carrousel, sur la Seine, à Paris. (4 800 mots & fig.)

1941 **621 .431**
Génie Civil, n° 3057-3058, 13-20 septembre, p. 120.
Nouveau **moteur à combustion interne**, à charbon pulvérisé. (1 100 mots & fig.)

1941 **624 .92 & 669 .1**
Génie Civil, n° 3063-3064, 25 octobre-1^{er} novembre, p. 183.
Le développement de l'emploi des **aciers de charpente** très résistants, du genre de l'acier allemand St. 52. (800 mots.)

1941 **624 .2**
Génie Civil, n° 3065-3066, 8-15 novembre, p. 193.
HAEGER (H.). — Formules pratiques pour le calcul des **poutres continues à travées inégales**. (3 000 mots & fig.)

1941 **669 .1**
Génie Civil, n° 3065-3066, 8-15 novembre, p. 196.
MERKLEN (J.) & VALLOT (E.). — Ensemble des conditions de fabrication et de recette des **aciers au carbone** et du **fer** en vue d'une standardisation générale des spécifications à imposer aux producteurs. (2 000 mots.)

1941 **669 .1**
Génie Civil, n° 3065-3066, 8-15 novembre, p. 200.
CHARPY (G.). — Les **traitements thermiques des aciers**. (2 000 mots & fig.)

1941 **624 .8 (.44) & 665 .882 (.44)**
Génie Civil, n° 3065-3066, 8-15 novembre, p. 202.
Le renforcement par soudure autogène du **pont tournant** de Brest. (1 500 mots & fig.)

1941 **62. (01 & 721 .1**
Génie Civil, n° 3067-3068, 22-29 novembre, p. 215.
CAUFOURIER (P.). — Les efforts de tension développés dans les **massifs de fondation**. (2 500 mots & fig.)

1941 **669**
Génie Civil, n° 3069-3070, 6-13 décembre, p. 238.
KIMPFILIN (G.). — Études sur les **alliages d'aluminium** faites par l'« Istituto sperimentale dei Metalli leggeri » de Milan. (2 200 mots, 6 tableaux & fig.)

1941 **385. (09 .1 (.66**
Génie Civil, n° 3071-3072, 20-27 décembre, p. 257.
CALFAS (P.). — Le Chemin de fer Méditerranéen Niger ou **Transsaharien**. (5 000 mots & fig.)

1941 **62. (01 & 6**
Génie Civil, n° 3071-3072, 20-27 décembre, p. 261.
FREYSSINET. — Une révolution dans l'art de bâtir les **constructions précontraintes**. (6 000 mots & fig.)

1942 **60**
Génie Civil, n° 3073-3074, 3-10 janvier, p. 11.
DANTIN (Ch.). — Valeur comparée des principaux **carburants de remplacement**. (2 800 mots & tableau.)

1942 **625 .13 (.493**
Génie Civil, n° 3073-3074, 3-10 janvier, p. 14.
La **ventilation** du souterrain de jonction entre les gars du Nord et du Midi, à Bruxelles. (1 000 mots & fig.)

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1946 **621 .431 .72 (.44**
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ZENS. — **Transformation de locomotives légères** (vd d'un mètre) en locos-tracteurs. (900 mots & fig.)

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1946 **621 .431 .**
Mécanique, janvier, p. 13.
Choix des **moteurs Diesel** pour la traction sur rail (800 mots & tableaux.)

1946 **6**
Mécanique, janvier, p. 21.
MICHEL (A.). — La fragilité de **revendu**. (4 500 mots & fig.)

L'Ossature métallique. (Bruxelles.)

1945 **625 .232 (.49**
L'Ossature métallique, septembre-octobre, p. 161.
Les **nouvelles voitures légères** des Chemins de fer Fédéraux suisses. (2 000 mots & fig.)

1945 **624 .7 (.44**
L'Ossature métallique, septembre-octobre, p. 166.
SECKLER (G.). — Nouveau **passage supérieur** en gars de Thionville. (1 500 mots & fig.)

1945 **62. (01 & 621 .3**
L'Ossature métallique, septembre-octobre, p. 173.
GERBEAUX (H.). — Le contrôle des **constructions soudées**. (4 000 mots & fig.)

1945 **625 .143 .4 (.49**
L'Ossature métallique, septembre-octobre, p. 183.
CAMPUS (R.). — Le **joint** de la voie ferrée. (3 500 mots & fig.)

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1945 **62. (01 & 669**
Revue de l'Aluminium, n° 114, août-septembre, p. 44.
TRILLAT (J.-J.). — La **microradiométallographie**.
2 500 mots & fig.)

1945 **625 .23 (.44)**
Revue de l'Aluminium, n° 114, août-septembre, p. 54.
GUERQUIN (M.). — La **voiture double articulée en**
alliages légers soudés de la S. N. C. F.-Nord. (1 200 mots
fig.)

1945 **621 .33 (.44)**
Revue de l'Aluminium, n° 115, octobre, p. 95.
VICTOR (M.). — L'**électrification** de la ligne Brive-
Montauban. (1 000 mots & fig.)

1945 **621 .33 (.44) & 669 (.44)**
Revue de l'Aluminium, n° 115, octobre, p. 99.
FAGET (G.). — La participation de l'aluminium dans
équipement électrique de la ligne Brive-Montauban.
1 700 mots & fig.)

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1942 **625 .26 (.44), 625 .28 (0 & 656 .223 (.44)**
Revue générale des chem. de fer, n° 2, mars-avril, p. 109.
MARTIN (C.) & NOUVION (F.). — La **réduction**
des immobilisations de matériel. (15 000 mots & fig.)

1942 **624 (.44) & 625 .13 (.44)**
Revue générale des chem. de fer, n° 2, mars-avril, p. 132.
CAYLA. — **Reconstruction des ouvrages d'art** de la
S. N. C. F. Dispositions techniques. (5 000 mots & fig.)

1942 **625 .131 .2 (.44)**
Revue générale des chem. de fer, n° 2, mars-avril, p. 149.
CHAN & TOURNEUR. — **Recherches actuelles** de la
S. N. C. F. en matière de **locomotives de types nouveaux**
ainsi que de modifications ou perfectionnements d'engins
de types classiques. (3 200 mots & fig.)

1942 **656 .223 .2 (.44)**
Revue générale des chem. de fer, n° 2, mars-avril, p. 157.
BURON. — La **répartition du matériel à marchandises**
de la Société Nationale des Chemins de fer français.
3 500 mots & 1 tableau.)

1942 **656 .222 .6 (.44) & 656 .225 (.44)**
Revue générale des chem. de fer, n° 2, mars-avril, p. 164.
LAURENT. — **Acheminement des transports P. V.** par
vagons complets. (5 200 mots & fig.)

1942 **625 .14 (01 & 625 .143 .5**
Revue générale des chem. de fer, n° 2, mars-avril, p. 186.
Le tampon de rail à ressorts-bagues (extrait de « Organ
für die Fortschr. des Eisenbahnw. » du 15 août 1939).
5 000 mots & fig.)

1942 **621 .133 .7 & 621 .134 .3**
Revue générale des chem. de fer, n° 2, mars-avril, p. 191.
Emploi de la vapeur surchauffée au lieu de la vapeur
saturée pour l'alimentation des **pompes et compresseurs**
de **locomotives**. (550 mots.)

1942 **621 .431 .72 (.44) & 662 (.44)**
Revue générale des chem. de fer, n° 3, mai-juin, p. 197.
TOURNEUR. — L'utilisation des **carburants de rem-**
placement sur le matériel de la S. N. C. F. (3 800 mots
& fig.)

1942 **656 .212 .9 (.44)**
Revue générale des chem. de fer, n° 3, mai-juin, p. 201.
FRATICELLI & GUILLERMONT. — L'**organisation**
de la messagerie-arrivée à Paris-Lyon. (5 000 mots & fig.)

1942 **656 .24 (.44)**
Revue générale des chem. de fer, n° 3, mai-juin, p. 208.
BARJOT. — Les efforts de la S. N. C. F. pour la
recherche des **propriétaires des épaves** recueillies après
le 30 juin 1940. (3 900 mots & fig.)

1942 **621 .131 .3 (.44) & 621 .134 .5 (.44)**
Revue générale des chem. de fer, n° 3, mai-juin, p. 212.
BOHL (G.). — Le **banc d'essais des graisseurs méca-**
niques à la station d'essais de Vitry de la S. N. C. F.
(1 200 mots & fig.)

1942 **385 .517 .7 (.44)**
Revue générale des chem. de fer, n° 3, mai-juin, p. 214.
Le **logement du personnel** de la S. N. C. F. (3 000
mots.)

1942 **621 .13 (0**
Revue générale des chem. de fer, n° 3, mai-juin, p. 217.
Une vue d'avenir sur la **locomotive à vapeur**. La loco-
motive de grande puissance (extrait de « Die Lokomo-
tive », juillet 1941). (1 600 mots.)

1942 **656 .212 .9 (.44) & 656 .225 (.44)**
Revue générale des chem. de fer, n° 4, juillet-août, p. 221.
DELACARTE. — Le **trafic des primeurs** du Sud-Est
de la France en 1941. Production et transports (voir
janvier et février 1940, article sur primeurs d'Algérie).
(10 000 mots, tableaux & fig.)

1942 **621 .131 .1 & 621 .135 (01**
Revue générale des chem. de fer, n° 4, juillet-août, p. 231.
CHAN. — Le **poids par essieu des locomotives** à
vapeur. (4 500 mots, 3 tableaux & fig.)

1942 **656 .21 (.44) & 656 .257 (.44)**
Revue générale des chem. de fer, n° 4, juillet-août, p. 236.
NARPS (R.) & CLOS (P.). — **Relevé graphique des**
mouvements exécutés dans la zone d'un poste d'aiguillage.
(1 500 mots & fig.)

1942 **016 (.44)**
Revue générale des chem. de fer, n° 4, juillet-août, p. 238.
DUGAS. — Le **centre de documentation** S. N. C. F.
(1 500 mots & fig.)

1942 **62 (01 & 625 .28**
Revue générale des chem. de fer, n° 4, juillet-août, p. 240.
Conférences techniques sur l'**allègement du matériel**
roulant des chemins de fer (29 mai, Paris). (2 800 mots.)

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1942 **624 .2**
Revue universelle des Mines, n° 4, p. 81.
GUILLEMIN & VAN WYNSBERGHE (R.). — Un
corollaire du **théorème de Weyrauch et Lévy**. (5 000 mots
& fig.)

1942 **669 .1**
Revue universelle des Mines, n° 6, p. 177.
HOUBAER (E.). — Trente ans de progrès dans la
métallurgie de l'acier. (7 000 mots.)

1942 **669**
Revue universelle des Mines, n° 7, p. 201.
DERCLAYE. — Trente années de progrès dans la
métallurgie de la fonte. (88 000 mots, 11 tableaux & fig.)

1942 **621 .82**
Revue universelle des Mines, n° 9, p. 377.
LELOUP (L.). — Essais comparatifs du comportement
de paliers équipés de coussinets en bronze ou en zamak.
(3 000 mots & fig.)

1942 **621 .83**
Revue universelle des Mines, n° 10, p. 411.
DEMARS (C.). — Considérations sur le tracé du profil
des dents des roues dentées droites extérieures. (3 000
mots, 2 tableaux & fig.)

1943 **62. (01 & 691**
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BATTÀ (G.). — Contribution à l'étude du mécanisme
de la désagrégation des bétons par les eaux sulfatées
riches. (5 500 mots, 4 tableaux & fig.)

1943 **621 .89**
Revue universelle des Mines, n° 5, p. 175.
HANOCQ (Ch.) & LELOUP (L.). — Etude du frotte-
ment en régime hydrodynamique et en régime onctueux.
(8 000 mots & fig.)

1943 **62. (01**
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CAMPUS (F.), DANTINNE (R.) & JACQUEMIN
(R.). — Appareil pour déterminer les efforts qui, dans
une éprouvette, soumise à la traction, amènent le début
des déformations permanentes perceptibles. (2 000 mots
& fig.)

1943 **62. (01, 624 .92 & 621 .392**
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CAMPUS (F.). — Rapport préliminaire concernant les
essais effectués sur modèles à trois dimensions de nœuds
rigides soudés. (1 600 mots & fig.)

La Technique moderne. (Paris.)

1941 **621 .431 .72 (.44) & 621 .433 (.44)**
La Technique moderne, n°s 13 et 14, 1^{er} et 15 juillet,
p. 215.
Autorails à gazogène à bois. (800 mots & fig.)

1941 **656 .257 (.43)**
La Technique moderne, n°s 13 et 14, 1^{er} et 15 juillet,
p. 216.
Système d'enclenchement automatique utilisé en Alle-
magne. (300 mots & fig.)

1941 **656 .254 (.43)**
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p. 216.
La protection des passages à niveau en Allemagne.
(1 000 mots & fig.)

1941 **621 .433**
La Technique moderne, n°s 15 et 16, 1^{er} et 15 août
p. 225.
DESBROSSE (G.) & FOUCHE (A.). — La combus-
tion dans les moteurs à injection. (2 500 mots & fig.)

1941 **625 .17**
La Technique moderne, n°s 15 et 16, 1^{er} et 15 août
p. 240.
L'entretien des voies par « soufflage mesuré ». (1 600
mots & fig.)

1941 **385 .(09 (.59)**
La Technique moderne, n°s 17 et 18, 1^{er} et 15 septembre
p. 270.
Le Chemin de fer du Yunnan. (1 000 mots.)

1941 **621 .132 .8 (.73) & 621 .335 (.73)**
La Technique moderne, n°s 19 et 20, 1^{er} et 15 octobre
p. 300.
La nouvelle locomotive turbo-électrique de l'« Union
Pacific Railroad ». (3 000 mots & fig.)

1943 **665. 88**
La Technique moderne, n°s 1 et 2, 1^{er} et 15 janvier
p. 1.
SALELLES (R.). — La soudure automatique (soudure
autogène). (5 000 mots & fig.)

1943/44 **621 .8**
La Technique moderne, n°s 3 et 4, 1^{er} et 15 février, p. 15.
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1^{er} et 15 avril, p. 53.
BRILLIE (H.). — La technique des coussinets et l'ex-
périmentation. (18 000 mots, tableaux & fig.)

1943 **665 .88**
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SALELLES (R.). — La soudure automatique. Ma-
chines oxy-acétyléniques pour soudure avec ou sans appor-
de métal. (4 000 mots & fig.)

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1941 **656 .24 (.43)**
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KITTEL. — Zur Frage der Gefährdungshaftung
(3 500 Wörter.)

1941 **385. (01 (.61 + .66**
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ZEISSLER. — Zum Bau der Transsaharabahn. (1 800
Wörter & Karte.)

1941 **656 (.460**
Archiv für Eisenbahnwesen, Mai/Juni, S. 486.
Gesetz betreffend die Regelung des Eisenbahnwesen
und des Kraftverkehrs vom 24. Januar 1941 in Spanien
(7 000 Wörter.)

1941 **385. (093 (.43))**
Archiv für Eisenbahnwesen, Juli/August, S. 537.
KITTEL (Th.). — Der **Plan eines « Bundes der deutschen Staatseisenbahnen »**, das Ende des preussisch-deutschen Eisenbahnkriegs. (Ein Beitrag zur Vorgeschichte der Reichseisenbahnen.) (6 000 Wörter.)

1941 **656 .214 (.43 + 494)**
Archiv für Eisenbahnwesen, Juli/August, S. 551.
KUNTZEMÜLLER (A.). — Der **Badische Bahnhof** in Basel (Basel D. R. B.). (14 000 Wörter & Bild.)

1941 **656 (.61)**
Archiv für Eisenbahnwesen, Juli/August, S. 581.
PASCHEN (W.). — Das **Verkehrswesen** und die Wirtschaft Französisch-Nordafrikas. (20 000 Wörter, Tabellen & Karte.)

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1940 **621 .138 .3 & 625 .2**
Der Bahn-Ingenieur, Nr. 33, 18. August, S. 413.
Häufige Fehler im **Betriebsmaschinendienst** und Massnahmen zur Bekämpfung. (4 600 Wörter.)

1940 **621 .137 .3 (.43)**
Der Bahn-Ingenieur, Nr. 34, 25. August, S. 425.
Die **Lokomotiv-Diensteinteilungen** bei der Deutschen Reichsbahn. (3 200 Wörter.)

1940 **625 .144 .2**
Der Bahn-Ingenieur, Nr. 34, 25. August, S. 428.
BROSE. — **Prüfung der Gleisfestpunkte** mit optischen Instrumenten. Hilfsplatte für Festpunkte neuer Form. 500 Wörter & Abb.)

1940 **656 .254 (.43)**
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Nr. 37, 15. September, S. 461.
KIRCH. — **Bahnselfstanschlussanlagen** (Basa). Die Leitungsausnutzung und Netzgruppenbildung. Fernwahl. 5 500 Wörter & Abb.)

1940 **62. (01)**
Der Bahn-Ingenieur, Nr. 36, 8. September, S. 449.
MÜLLER (E. A. W.). — Fortschritte im Bau von Hilfsmitteln für die **Magnetpulverprüfung**. (2 300 Wörter & Abb.)

1940 **669 .1 (.43)**
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1941 **621 .335 : 625 .42 (.43)**
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BENNINGHOFF (W.). — Die **neuen U-Bahn-Züge** der Berliner Verkehrs-Betriebe (BVG). (4 000 Wörter & Abb.)

1941 **621 .336**
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MALUSARDA (F.). — Untersuchungen über **Fahrleistungen**. (600 Wörter & 6 Tabellen.)

1941 **621 .335**
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AKERMANN (O.). — Beitrag zur Entwicklung von Ausrüstungen für **Einphasenlokomotiven**. (14 000 Wörter & Abb.)

1941 **621 .33 (.43)**
Elektrische Bahnen, Heft 8, August, S. 141.
USBECK (W.). — **Hamburger S-Bahn**, Stromart, Energieversorgung und ortsfeste Anlagen für den bisherigen Wechselstrom- und den künftigen Gleichstrombetrieb. (11 000 Wörter & Abb.)

1941 **621 .332**
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WEINRATH (H.). — Über die elektrischen Eigenschaften von **Wechselstrom-Übertragungssysteme**. (10 000 Wörter & Abb.)

1941 **621 .336**
Elektrische Bahnen, Heft 9, September, S. 176.
DRAEGER (W.). — Die Entwicklung der **Spannungssicherungen** für hohe Ströme. (1 200 Wörter & Abb.)

1941 **621 .33 & 691**
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BLATZ (H.). — Die **Kunststoffe im elektrischen Bahnbetrieb**. (3 000 Wörter & 4 Tafeln.)

1941/42 **621 .332 (.43)**
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NIBLER (H.). — **Fahrleitung aus Heimstoffen** für elektrischen Hauptbahnbetrieb. (5 800 Wörter, Tafeln & Abb.)

1941 **621 .332 (.43)**
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KOCI (A.). — Betriebserfahrungen mit **Bahnstrom-Fernleitungen** aus Heimstoffen. (3 200 Wörter, 3 Tafeln & Abb.)

1941 **621 .335 (.43)**
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TREICHTMEISTER (J.). — Die **elektrische Lokomotive Reihe E 45^a** der Deutschen Reichsbahn. (6 000 Wörter & Abb.)

1941 **621 .335 (.494)**
Elektrische Bahnen, Heft 11, November, S. 223.
STEINER (F.). — Die neuen **Schnell- und Güterzuglokomotiven** der Serie Ae4/6, Nr. 10801-10806 der Schweizerischen Bundesbahnen (SBB). (2 000 Wörter, Tabellen & Abb.)

1941 **621 .33 (.45)**
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SEMENZA (M.). — Eine neuzeitliche **elektrische Bahn**. (3 000 Wörter & Abb.)

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KÜHNEL. — **Entwicklung der Stähle** für Reichsbahnbauwerke und -fahrzeuge sowie Oberbau in Wechselwirkung von Beanspruchung und Formgebung. (5 400 Wörter & Abb.)

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 Akkumulatorenforschung. (1 300 Wörter & Abb.)

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 Glasers Annalen, Heft 2, 15. Januar, S. 11.
 PETERS (H.). — Dampfkolbenpumpen für **Bremsluft-
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1941 **656 .211 .7 (.45)**
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 WERNEKKE. — Italienische **Eisenbahnfähren**. (3 000
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1941 **625 .616**
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 SCHROETER (H.). — Die **Lokomotiven** der deutschen
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1941 **625 .232 (.43)**
 Glasers Annalen, Heft 5, 1. März, S. 64.
 BETHGE. — Die neuen **D-Zugwagen** der Deutschen
 Reichsbahn. (4 200 Wörter & Abb.)

1941 **625 .42 (.43)**
 Glasers Annalen, Heft 5, 1. März, S. 70.
 KNIFFLER. — Die **Fortentwicklung der S-Bahnen**
 bei der Deutschen Reichsbahn. (12 000 Wörter & Abb.)

1941 **625 .253**
 Glasers Annalen, Heft 5, 1. März, S. 87.
 MÖLLER (E.). — **Gleischutz**, ein Weg zur Hoch-
 leistungsbremse. (11 000 Wörter & Abb.)

1941 **621 .392 (.43) & 665 .882 (.43)**
 Glasers Annalen, Heft 5, 1. März, S. 100.
 KÜHNEL. — Die Entwicklung der **Schweisstechnik**
 bei der Reichsbahn. (6 000 Wörter.)

Gleistechnik und Fahrbahnbau. (Karlsruhe.)

1942 **625 .143 (0)**
 Gleistechnik und Fahrbahnbau, Heft 7/8, 15. April,
 S. 25; Heft 9/10, 15. Mai, S. 33.
 RAAB (F.). — **Raddruck und Schienengewicht**.
 (4 000 Wörter, Tabellen & Abb.)

1942 **625 .143 .3**
 Gleistechnik und Fahrbahnbau, Heft 9/10, 15. Mai, S. 38.
 v. PISTOHLKORS (E.). — Über den Einfluss der
 Richtwalzen auf die **Schienenbruchgefahr**. (600 Wörter.)

1942 **625 .143 .1**
 Gleistechnik und Fahrbahnbau, Heft 11/12, 15. Juni,
 S. 41; Heft 13/14, 15. Juli, S. 49.
 GÖTTLICHER (J.). — Die Berechnung **rillenschienen-
 ähnlicher Profile**. (3 500 Wörter & Abb.)

1942 **625 .143. (0)**
 Gleistechnik und Fahrbahnbau, Heft 11/12, 15. Juni,
 S. 47.
 WENTZEL. — **Raddruck, Schienengewicht und Wider-
 standsmoment**. (400 Wörter & 1 Tabelle.)

1942 **625 .143 .4**
 Gleistechnik und Fahrbahnbau, Heft 13/14, 15. Juli,
 S. 52.
 HALTER (G.). — Betrachtungen zum **Schienenstoss**
 (1 000 Wörter & Abb.)

1942 **621 .135 .4 & 625 .21**
 Gleistechnik und Fahrbahnbau, Heft 15/16, 15. August,
 S. 57; Heft 17/18, 15. September, S. 65.
 RISCH & LUDWIG. — Über den **Einlauf von Eisen-
 bahnfahrzeugen in Krümmungen** ohne Überhöhung und
 Übergangsbogen. (2 500 Wörter, Tabellen & Abb.)

1942 **625 .143 .4**
 Gleistechnik und Fahrbahnbau, Heft 15/16, 15. August,
 S. 61.
 PÖSENTRUP (H.). — Beitrag zur **Schienenstoss-
 frage**. (2 100 Wörter & Abb.)

1942 **625 .14 (.489)**
 Gleistechnik und Fahrbahnbau, Heft 15/16, 15. August,
 S. 63.
 Ein **neuer Oberbau** der Dänischen Staatsbahn. (1 000
 Wörter.)

Die Lokomotive. (Bielefeld-Berlin.)

1940 **621 .431 .7**
 Die Lokomotive, Nr. 12, Dezember, S. 165.
 HERRMANN (H.). — **360 PS Diesel-Lokomotive** mit
 Krupp-Strömungsgetriebe. (2 200 Wörter & Abb.)

1940 **621 .335 (.43)**
 Die Lokomotive, Nr. 12, Dezember, S. 169.
 OHL. — **Abraum-Lokomotiven** von 150 t. (1 700 Wör-
 ter & Abb.)

1940 **621 .133 .3**
 Die Lokomotive, Nr. 12, Dezember, S. 171.
 PFEIFER (H.). — **Herabsetzung der Dampf tempera-
 turen** bei Heissdampflokomotiven. (Schluss.) (2 700 Wör-
 ter & Abb.)

1941 **621 .134 .1**
 Die Lokomotive, Nr. 1, Januar, S. 1; Nr. 2, Februar,
 S. 17.
 RÜGGERBERG (G.). — Entwicklung der **Lokomotiv-
 Schieber-Steuerungen**. (4 500 Wörter & Abb.)

1941 **385. (09 (.58)**
 Die Lokomotive, Nr. 1, Januar, S. 7.
 WEIDNER. — Die **Eisenbahnen Turkistans**. (2 000
 Wörter & Karte.)

1941 **625 .21**
 Die Lokomotive, Nr. 1, Januar, S. 11.
 MEINEKE (F.). — **Lenkgestelle** für mehr als zwei
 Achsen. (500 Wörter & Abb.)

1941 **625 .215 & 625 .25**
 Die Lokomotive, Nr. 2, Februar, S. 15.
 RIHOSEK (J.). — **Drehgestell und Bremsgestänge**
 (800 Wörter & Abb.)

1941 **621 .431 .72 & 656 .212 .1**
 Die Lokomotive, Nr. 3, März, S. 33.
 NEUMANN (A.). — **Dieselhydraulische Lokomotive**
 im Verschiebedienst. (4 500 Wörter & Abb.)

1941 **656 .212 .5**
 Lokomotive, Nr. 4, April, S. 49.
MITTE (Fr.). — Eine neuartige **Rangier-Lokomotive**.
 1000 Wörter & Abb.)

1941 **621 .33 (.460)**
 Lokomotive, Nr. 4, April, S. 59.
Elektrifizierung spanischer Eisenbahnen. (1 000 Wör-
 & Karte.)

1941 **621 .132 .8 (.437)**
 Lokomotive, Nr. 4, April, S. 60.
Dampf-Gepäcktriebwagen für die Slowakischen Staats-
 bahnen. (500 Wörter & Abb.)

rgan für die Fortschritte des Eisenbahnwesens.
 (Berlin.)

1940 **621 .431 .72 (.83)**
 rgan für die Fortschritte des Eisenbahnwesens, Heft 21,
 1. November, S. 331.
SCHMID (J.). — **Dreiteiliger dieselelektrischer Trieb-**
zug der Chilenischen Staatsbahn. (8 000 Wörter
 Abb.)

1940 **621 .431 .72 (.493)**
 rgan für die Fortschritte des Eisenbahnwesens, Heft 21,
 1. November, S. 345.
 Die **Dieseltriebwagen** in Belgien. (2 200 Wörter
 Abb.)

1940 **621 .431 .72 (.460)**
 rgan für die Fortschritte des Eisenbahnwesens, Heft 21,
 1. November, S. 349.
 Entwicklung und Ergebnisse der **Triebwagen** in Spa-
 n. (1 300 Wörter.)

1940 **656 .212 .5**
 rgan für die Fortschritte des Eisenbahnwesens, Heft 22,
 15. November, S. 351.
SCHMITZ (W.). — Die Betriebsverhältnisse bei der
gildung auf Gefällbahnhöfen für Höchstleistung.
 1000 Wörter, 5 Zahlentafeln & Abb.)

1940 **621 .431 .72 (.43) & 625 .235 (.43)**
 rgan für die Fortschritte des Eisenbahnwesens, Heft 23,
 1. Dezember, S. 367; Heft 24, 15. Dezember, S. 383.
TASCHINGER (O.). — **Werkstoffprobleme** für nicht-
 gende Bauteile von Trieb-, Steuer- und Beiwagen.
 1000 Wörter & Abb.)

1940 **621 .135 .4 & 625 .215**
 rgan für die Fortschritte des Eisenbahnwesens, Heft 24,
 15. Dezember, S. 394.
Drehgestelle mit ideellem Drehpunkt. (800 Wörter
 Abb.)

1941 **621 .335 (.83)**
 rgan für die Fortschritte des Eisenbahnwesens, Heft 1,
 1. Januar, S. 1.
 von **WALDSTÄTTEN**. — **Dreiteilige Oberleitungstrieb-**
gen für die Chilenische Staatsbahn. (3 500 Wörter,
 Tafel & Abb.)

1941 **625 .253**
 Organ für die Fortschritte des Eisenbahnwesens, Heft 1,
 1. Januar, S. 5.
HILDEBRAND (W.). — Vergrößerung der **Brems-**
kraft von Druckluftbremsen der Güterwagen mit Rück-
 sicht auf die Belastung. (3 600 Wörter & Abb.)

1941 **621 .135 .4 & 625 .215**
 Organ für die Fortschritte des Eisenbahnwesens, Heft 1,
 1. Januar, S. 11.
ECKHARDT (F.). — Der **Anlaufwinkel** bei Schienen-
 fahrzeugen. (1 000 Wörter & Abb.)

Die Reichsbahn. (Berlin.)

1941 **385. (093 (.436)**
 Die Reichsbahn, Heft 24/26, 11./18./25. Juni, S. 231.
FEILER (K.). — Zur **Gründungsgeschichte** der Eisen-
 bahn Wien-Wiener Neustadt. (13 000 Wörter & Abb.)

1941 **385 .571 (.43)**
 Die Reichsbahn, Heft 27/28, 2./9. Juli, S. 259.
GOEBEL (H. H.). — Gedanken zur Ausbildung unse-
 rer jungen **Rechtswahrer**. (9 000 Wörter.)

1941 **625 .232 (.43)**
 Die Reichsbahn, Heft 27/28, 2./9. Juli, S. 267.
 Neue **Einbett-Schlafwagen** der Mitropa. (1 800 Wörter
 & Abb.)

1941 **625 .174 (.43)**
 Die Reichsbahn, Heft 36/37, 3./10. September, S. 335.
KAISER (O.). — Massnahmen zur Verhütung von
Betriebsstörungen durch Frost und Schnee. (3 000 Wör-
 ter & Abb.)

1941 **656 .211**
 Die Reichsbahn, Heft 40/41, 1./8. Oktober, S. 375.
DERIKARTZ. — Grossstädtische **Personenbahnhöfe**.
 (7 000 Wörter & Abb.)

1941 **656 .28 (.43)**
 Die Reichsbahn, Heft 51/53, 17./24./31. Dezember, S. 466.
DZAAK (G.). — **Unfallverhütung**-Jahresstatistik 1940
 und ihre Lehren. (6 000 Wörter & Abb.)

1942 **385 .113 (.43)**
 Die Reichsbahn, Heft 1/2, 7./14. Januar, S. 6.
 Die **Deutsche Reichsbahn** im Jahre 1941. (2 000 Wör-
 ter.)

Zeitschrift des Vereines deutscher Ingenieure. (Berlin.)

1940 **62. (01)**
 Zeitschrift des Vereines deutscher Ingenieure, Nr. 48,
 30. November, S. 929.
DIERGARTEN (H.). — Gefüge-Richtreihen zur **Werk-**
stoffprüfung. (2 100 Wörter & Abb.)

1940 **625 .13 (.42 + .492)**
 Zeitschrift des Vereines deutscher Ingenieure, Nr. 48,
 30. November, S. 932.
PROETEL (H.). — Die neuen **Unterwassertunnel**
 unter dem Mersey-Fluss bei Liverpool und unter der
 Maas bei Rotterdam. (4 500 Wörter & Abb.)

1940 **621 .431 .72**
Zeitschrift des Vereines deutscher Ingenieure, Nr. 48.
30. November, S. 938.
Prüfstandversuche an einem **Flüssigkeitsgetriebe** für
Diesellokomotiven. (600 Wörter & Abb.)

1940 **624 .2**
Zeitschrift des Vereines deutscher Ingenieure, Nr. 51,
21. Dezember, S. 1012.
Untersuchungen an **Steifknoten-Modellen**. (1 400 Wör-
ter, 1 Zahlentafel & Abb.)

1940 **621 .82**
Zeitschrift des Vereines deutscher Ingenieure, Nr. 52,
23. Dezember, S. 1017.
SCHMID (E.) & WEBER (R.). — Erfahrungen mit
Zinklagern. (2 000 Wörter, 5 Zahlentafeln & Abb.)

1941 **669**
Zeitschrift des Vereines deutscher Ingenieure, Nr. 1,
4. Januar, S. 8.
ALTMANN (F. G.). — **Werkstoffumstellung** im Ge-
triebbau. (5 600 Wörter & Abb.)

1941 **62. (01 & 669**
Zeitschrift des Vereines deutscher Ingenieure, Nr. 1,
4. Januar, S. 15.
BUCHMANN (W.). — Dauerfestigkeitseigenschaften
der **Magnesiumlegierungen**. (3 500 Wörter, 1 Zahlentafel
& Abb.)

1941 **621 .89**
Zeitschrift des Vereines deutscher Ingenieure, Nr. 2,
11. Januar, S. 33.
THOMAS (K.). — Die Wiedergewinnung gebrauchter
Mineralöle. (6 500 Wörter & Abb.)

1941 **621 .392**
Zeitschrift des Vereines deutscher Ingenieure, Nr. 2,
11. Januar, S. 45.
SCHMIDT (H.). — Elektrisches **Unterwasserschwei-**
sen und -schneiden. (3 000 Wörter & Abb.)

Zeitung des Vereins Mitteleuropäischer Eisenbahnverwaltungen. (Berlin.)

1940 **385. (09 .460)**
Zeitung des Vereins mitteleurop. Eisenbahnverw., Nr. 42,
17. Oktober, S. 533.
Eisenbahnen im neuen Spanien. (2 500 Wörter.)

1940 **385. (09 .3 (.42) & 623 (.42)**
Zeitung des Vereins mitteleurop. Eisenbahnverw., Nr. 43,
24. Oktober, S. 541.
WERNEKKE. — Die **englischen Eisenbahnen** im
Kriege. (4 500 Wörter.)

1940 **621 .431 .72 (.45) & 621 .435 (.45)**
Zeitung des Vereins mitteleurop. Eisenbahnverw., Nr. 44,
31. Oktober, S. 551.
GRAZZINI (M.). — **Holzkohlengas-Triebwagen** der
Italienischen Staatsbahnen. (1 500 Wörter & Abb.)

1940 **385. (09 .3 (.44) & 623 (.44)**
Zeitung des Vereins mitteleurop. Eisenbahnverw., Nr. 42,
7. November, S. 563.
WERNEKKE. — Die **französischen Eisenbahnen** im
Kriege. (4 300 Wörter.)

1940 **625 .6**
Zeitung des Vereins mitteleurop. Eisenbahnverw., Nr. 42,
7. November, S. 568.
LILLIENDAHL (A.). — **Unterschied-Lenkzeug** zur
Gleitbarmachung von normalen Nutzkraftwagen. (3 600
Wörter & Abb.)

1940 **385 .517 .7 (.44)**
Zeitung des Vereins mitteleurop. Eisenbahnverw., Nr. 42,
14. November, S. 579.
PETZOLDT (A.). — **Wohnungsfürsorge** der Deutschen
Reichsbahn im national-sozialistischen Reich. (8 400 Wör-
ter & Abb.)

1940 **656 (.49)**
Zeitung des Vereins mitteleurop. Eisenbahnverw., Nr. 42,
28. November, S. 607.
TISSOT VAN PATOT (J. P. B.). — Der **Nieder-**
ländische Verkehr. (3 000 Wörter.)

1940 **656 .212**
Zeitung des Vereins mitteleurop. Eisenbahnverw., Nr. 42,
28. November, S. 612.
WITTE (Fr.). — **Rangiergerät** mit seitlich ausschwei-
barer Zug- und Stossvorrichtung. (2 500 Wörter & Abb.)

Zeitschrift für das gesamte Eisenbahn- Sicherungs- und Fernmeldewesen. (Berlin.)

1942 **656 .2**
Zeitschr. für das ges. Eisenb.-Sicherungs- und Fernmel-
wesen, Nr. 1, 10. Januar, S. 1; Nr. 4, 10. März,
S. 21; Nr. 6/7, 20. Mai, S. 41; Nr. 14/15, 20. No-
vember, S. 91.

HOFMANN (F.). — Die bisherige Entwicklung der
optischen Zugschlussmelders. (9 000 Wörter & Abb.)

1942 **654 (.44)**
Zeitschr. für das ges. Eisenb.-Sicherungs- und Fernmel-
wesen, Nr. 5, 10. April, S. 29.
Neuerungen und Versuche im **Fernmeldewesen** bei der
Deutschen Reichsbahn im Jahre 1941. (2 000 Wörter.)

1942 **656 .256 (.42)**
Zeitschr. für das ges. Eisenb.-Sicherungs- und Fernmel-
wesen, Nr. 6/7, 20. Mai, S. 37; Nr. 8, 10. Juni,
S. 51.
SPERLICH (F.). — Einführung der **Einheitsstrecke-**
blockung in Sicherungsanlagen österreichischer Bauart.
(4 200 Wörter & Abb.)

1942 **656 .257 & 725**
Zeitschr. für das ges. Eisenb.-Sicherungs- und Fernmel-
wesen, Nr. 8, 10. Juni, S. 47; Nr. 10/11, 20. August,
S. 65.
KÖRBER (W.). — Durchbildung der **Stellwerks-
gebäude**. (4 300 Wörter, Tafeln & Abb.)

1942/43 **656 .25 (.44)**
tschr. für das ges. Eisenb.-Sicherungs- und Fernmelde-
wesen, Nr. 9, 10. Juli, S. 55; Nr. 1, 10. Januar,
S. 1; Nr. 2/3, 20. Februar, S. 9; Nr. 6/7, 20. Mai,
S. 36; Nr. 8, 10. Juni, S. 41.
ASSE (H. W.). — Ausschnitte aus dem **französischen**
nalwesen. (12 000 Wörter & Abb.)

1942/43 **654 & 656 .254**
tschr. für das ges. Eisenb.-Sicherungs- und Fernmelde-
wesen, Nr. 10/11, 20. August, S. 63; Nr. 12, 10. Sep-
tember, S. 71; Nr. 4, 10. März, S. 17; Nr. 5,
10. April, S. 27.
MÜHLBRETT (Karl). — Das **Nebensprechen auf**
eileitungen. (10 000 Wörter & Abb.)

In English.

Engineer. (London.)

1945 **621 .133 .1 (.42)**
ineer, No. 4688, November 16, p. 388.
oil-burning locomotives of the Great Western Railway.
(0 words & fig.)

1946 **656 .211 .5 (.42)**
ineer, No. 4701, February 15, p. 149.
M. S. experimental **station building**. (1 500 words
& fig.)

1946 **621 .132 .3 (.42)**
ineer, No. 4701, February 15, p. 162.
OX (E. S.). — **Locomotive development** on the
M. S., 1923-1932. (1 800 words.)

1946 **621 .6**
ineer, No. 4702, February 22, p. 168.
EACHAM (T. E.). — High-pressure gear **pumps**.
(500 words & fig.)

1946 **621 .132 .8 (.68)**
ineer, No. 4703, March 1, p. 195.
ew **Beyer-Garratt locomotives** for S. A. R. (2 400
ds & fig.)

1946 **385. (09 (.42)**
ineer, No. 4704, March 8, p. 220.
M. S. **Railway: 1923-1946**. (1 900 words.)

1946 **624 .63 (.494)**
ineer, No. 4704, March 8, p. 227.
urstenland Bridge, Switzerland. (350 words & fig.)

1946 **621 .132 .3 (.4)**
ineer, No. 4705, March 15, p. 243.
The **Liberation 2-8-0 locomotive**. (3 300 words & fig.)

1946 **621. (06 (.42)**
ineer, No. 4707, March 29, p. 291.
stitution of Mechanical Engineers : **Annual Report**.
(000 words.)

Engineering News-Record. (New York.)

1940 **624 .63 (.73) & 721 .4 (.73)**
Engineering News-Record, November 21, p. 56.
WEILER (Joseph J.). — Field-spliced **precast con-**
crete arches for fireproof garage (arch frames and roof
slabs made in three sections and spliced after erection.)
(1 000 words & fig.)

1940 **625 .111 (.73)**
Engineering News-Record, December 19, p. 48.
HUGUENIN (Sydney Arnes). — 3-mile depressed
grade elimination (4 steam-operated and electric tracks
in common cut on original rights-of-way.) (3 200 words
& fig.)

1940 **62 (01 (.73) & 691 (.73)**
Engineering News-Record, December 19, p. 64.
HAMMOND (L. C.). — Good **concrete** stays good
in New York seawater. (1 700 words & fig.)

1940 **624 .2 (.73) & 691 (.73)**
Engineering News-Record, December 19, p. 70.
HADLEY (Horner M.). — **Precast box beams** for
high strength (used for short-span bridges.) (1 300 words
& fig.)

1941 **624 .51**
Engineering News-Record, October 23, p. 97.
MADJESKI and MASTERS. — **Suspension bridges**
and wind resistance (advocating decrease, in pressure
areas or additional bracing). (5 000 words & fig.)

1941 **623 (.73) & 725 (.73)**
Engineering News-Record, October 23, p. 105.
Defense-developed buildings. — A series of 12 articles
showing new trends in factory, office, etc., building in
the U. S. A. (20 000 words & fig.)

Journal, Permanent Way Institution. (London.)

1940 **621 .392 (.66) & 625 .142 .3 (.66)**
Journal, Permanent Way Institution, April, p. 43.
DUNCOMBE BINDLEY (H.). — **Reconditioning of**
steel sleepers by electric arc welding. (1 500 words & fig.)

1940 **624 .63 (.41)**
Journal, Permanent Way Institution, April, p. 55.
BEATTY (W. F.). — **Reinforced concrete bridges**.
(3 600 words & fig.)

1940 **625 .172 (.66)**
Journal, Permanent Way Institution, April, p. 68 et 78.
AHMED EFF. FADL. — **Sand dunes and drift sand**,
Port Sudan line. (2 500 words & fig.)
AHMED EFF. MUSTAFA EL HAG. — **Sand dunes**.
(1 500 words & fig.)

1940 **625 .14 (.42)**
Journal, Permanent Way Institution, April, p. 87;
August, p. 150.
SWINNERTON (N. W.). — **Materials under trial** on
the London Midland and Scottish Railway. (5 000 words
& fig.)

1940 **625 .142 .2 (.42)**
Journal, Permanent Way Institution, August, p. 125.
The question of **substitutes for timber sleepers**. (1 100
words.)

1940 **625 .174 (.42)**
Journal, Permanent Way Institution, August, p. 163.
The West Highland **snowstorm** (January-February, 1940). (2 000 words & fig.)

1940 **625 .17 & 656 .222 .4**
Journal, Permanent Way Institution, August, p. 169.
HUTT (E. T.). — Space, time and the engineering department. Some notes on speed, gradients and curvature. (5 000 words & fig.)

1940 **621 .392 (.42) & 624 (.42)**
Journal, Permanent Way Institution, December, p. 211.
CLARK (H. W.). — Electric arc welding on structures of London Transport (Railways). (6 000 words & fig.)

1940 **621 .13 & 625 .14**
Journal, Permanent Way Institution, December, p. 230.
PEARSON (H. M.). — Relationship between the track and the locomotive. (9 000 words & fig.)

1940 **625 .13 (.54)**
Journal, Permanent Way Institution, December, p. 249.
SITARAM (J.). — Madras and Southern Mahratta Railway. Strengthening of tunnel No. 12 between Castle Rock and Caranzol. (2 000 words & fig.)

1940 **625 .14 (01 & 656 .222 .1**
Journal, Permanent Way Institution, December, p. 257.
Effect of heavier traffic on permanent way and works. (2 500 words.)

Modern Transport. (London.)

1945 **621 .132 .8 (.73)**
Modern Transport, September 8, p. 5.
POULTNEY (E. C.). — Pennsylvania 4-4-4 type locomotives. Remarkable test results. (1 800 words & fig.)

1945 **385. (061 (.4)**
Modern Transport, September 8, p. 11.
Conference on **Inland Transport in Europe.** Report by M. Jean **LEVY.** (1 400 words.)

1945 **621 .132 .3 (.71)**
Modern Transport, September 15, p. 17.
New C. P. R. locomotives. Features of a 4-6-2 class. (250 words & fig.)

1945 **656 (.82)**
Modern Transport, September 22, p. 3.
Future of Argentine **transport.** An Institute of transport discussion. Position of the Railways. (2 000 words.)

1945 **656 .283 (.42)**
Modern Transport, September 22, p. 11.
Starting against signals. Report on the Caterham collision. (1 100 words.)

1945 **621 .431 .72 (.82)**
Modern Transport, September 29, p. 13.
Argentine State Railways. Realignment and **Diesel traction.** (500 words & fig.)

1945 **385. (09 (.48)**
Modern Transport, October 6, p. 3.
Norwegian Railway progress. **Gauge unification and electrification.** Central Station for Oslo. (500 words & fig.)

1945 **625 .232 (.4)**
Modern Transport, October 6, p. 9.
New standard coach on Southern Railway. Innovation in heating. (400 words & fig.)

1945 **656 .253 (.4)**
Modern Transport, October 6, p. 13; October 13, p. 1.
Overhaul of signal apparatus. London Transport methods. (1 000 words & fig.)

1945 **656 .234 (.4)**
Modern Transport, October 6, p. 15.
Reservation of train seats. Great Northern of Ireland practice. (400 words & fig.)

1945 **625 .**
Modern Transport, October 13, p. 7.
GRAFF-BAKER (W. S.). — Railway coach body. Modern tendencies in design. (1 000 words & fig.)

1945 **656 .254 (.4)**
Modern Transport, October 20, p. 3.
Reorganized **traffic control** on the L. M. S. Advantages of decentralisation. (1 500 words & fig.)

1945 **621 .132 .3 (.4)**
Modern Transport, October 20, p. 11.
L. N. E. R. rebuild **Pacific type locomotive.** Increased tractive power. (800 words, 1 table & fig.)

Railway Age. (New York.)

1941 **621 .131 .3 (.73) & 621 .133 (.7)**
Railway Age, January 18, p. 177.
COLLINS (W. F.). — Standing locomotive tests of New York Central. Investigation results in substantial increase of boiler evaporative capacity and lowering exhaust pressure. (4 500 words & fig.)

1941 **625 .143 .3 (.73) & 625 .172 (.7)**
Railway Age, January 18, p. 182.
GENNETT (C. W. Jr.). — Continuous research increased the integrity of **rail testing.** Progress made in rail testing in the past decade (Sperry detector car). (4 500 words & fig.)

1941 **621 .134 .3 (.7)**
Railway Age, March 8, p. 405.
Poppet valves (Franklin system) prove capacity of Pennsylvania R. R. test plant at Altoona. K4s Pacific develops 4099 I. H. P. at 100 m. p. h. with steam rate one-third less than piston-valve locomotive. (1 400 words & fig.)

1941 **625 .111 (.73) & 625 .162 (.7)**
Railway Age, March 8, p. 416.
Federal **grade-crossing program** makes steady headway. Priority formula (for determining hazard ratings of individual crossings.) (2 000 words & fig.)

1946 **621 .131 .1**
 Railway Age, February 9, p. 316.
WYNNE (F. E.). — Comparable locomotive ratings. (1 000 words & fig.)

1946 **614 .8 (.73)**
 Railway Age, February 9, p. 319.
BENJAMIN (H. I.). — Railroad fires and how to prevent them. (1 200 words & fig.)

1946 **656 .284 (.73)**
 Railway Age, February 9, p. 325.
 Bureau reports fewer casualties from **locomotive accidents** during 1945. (2 000 words & tables.)

1946 **625 .241 (.73)**
 Railway Age, February 16, p. 354.
 Great Northern **general service gondolo.** (1 500 words & fig.)

1946 **656 .254 (.73)**
 Railway Age, February 16, p. 356.
 Baltimore & Ohio installs **yard radio.** (1 800 words & fig.)

1946 **621 .138 (.73)**
 Railway Age, February 16, p. 366.
TODD (J. N.). — Small locomotive scales have advantages. (1 600 words & fig.)

1946 **651 (.73)**
 Railway Age, February 23, p. 394.
BARNGROVE (J. L. Jr.). — Novel system mechanizes 1 car records. (600 words, table & fig.)

1946 **625 .13 (.73)**
 Railway Age, February 23, p. 399.
 Hoosac Tunnel gets new **propeller fans.** (1 000 words & fig.)

1946 **621 .431 .72 (.73) & 656 .212 .5 (.73)**
 Railway Age, February 23, p. 402.
Diesel trailers for hump operation (New York Central). (1 000 words & fig.)

1946 **656 .224 (.73)**
 Railway Age, February 23, p. 404.
Passenger officers consider the future. (2 000 words.)

1946 **656 .254 (.73)**
 Railway Age, March 2, p. 457.
PRENDERGAST (L. J.). — Train communication finding its place. (2 100 words & fig.)

1946 **625 .244 (.73)**
 Railway Age, March 2, p. 459.
 Burlington to test **refrigerator cars.** (1 800 words & fig.)

1946 **625 .142 .2 (.73)**
 Railway Age, March 9, p. 494; March 16, p. 538.
New process seasons ties overnight. (5 500 words & fig.)

1946 **625 .214 (.73)**
 Railway Age, March 9, p. 504.
 New York Central develops **hot-box alarm.** (2 800 words & fig.)

1946 **625 .254 (.73)**
 Railway Age, March 9, p. 509.
Yard radio tests on the Reading. (1 500 words & fig.)

1946 **621 .131 .2 & 621 .133 .3**
 Railway Age, March 16, p. 544.
HARRISON (J. H.). — Relation of boiler capacity to firing rate. (500 words.)

Railway Gazette. (London.)

1945/46 **621 .132 .3 (.42)**
 Railway Gazette, No. 25, December 21, p. 640; No. 26, December 28, p. 664; No. 1, January 4, p. 12; No. 2, January 11, p. 38.
Somes notes on the « Merchant Navy » class locomotives, Southern Railway. (4 000 words & fig.)

1945 **621 .132 .3 (.42)**
 Railway Gazette, No. 25, December 21, p. 645.
The oldest L. N. E. R. Pacific is rebuilt. (700 words & fig.)

1945 **625 .17 (.42) & 625 .42 (.42)**
 Railway Gazette, No. 26, December 28, p. 666.
London transport track conversion. (350 words & fig.)

1946 **656 .212 (.42)**
 Railway Gazette, No. 1, January 4, p. 15.
Mechanised goods shed operation, L. M. S. R. (1 900 words & fig.)

1946 **625 .232 (.42)**
 Railway Gazette, No. 1, January 4, p. 25.
Automat buffet cars proposed on G. W. R. (150 words & fig.)

1946 **625 .232 (.42)**
 Railway Gazette, No. 2, January 11, p. 40.
L. M. S. R. new composite third class brake vehicles. (600 words & fig.)

1946 **656 .284 (.42)**
 Railway Gazette, No. 2, January 11, p. 46.
Ministry of War Transport accident report (between Trevor and Llangollen, G. W. R., September 7, 1945.) (1 700 words & fig.)

1946 **621 .133 .1 (.42)**
 Railway Gazette, No. 3, January 18, p. 65.
Oil-burning locomotives on the G. W. R. Conversion of heavy freight tender and tank engines. (450 words & fig.)

1946 **621 .132 .3 (.42)**
 Railway Gazette, No. 3, January 18, p. 75.
Somes notes on the « Merchant Navy » class locomotives of the Southern Railway. Summary of the discussion on Mr. Bulleid's paper to the Institution of Mechanical Engineers. (1 600 words.)

1946 **656 .285 (.42)**
 Railway Gazette, No. 3, January 18, p. 80.
Ferryhill (L. N. E. R.) accident inquiry. (500 words.)

- 1946** **621 .131 .2 (.42)**
 Railway Gazette, No. 4, January 25, p. 94.
The running man's ideal locomotive. Feature of design and construction which make for reliability in service and ease of maintenance. (2 500 words.)
- 1946** **623 (.42) & 624 .2 (.42)**
 Railway Gazette, No. 4, January 25, p. 95.
Standard military railway bridges. A description of the Everall sectional truss bridge. (2 800 words & fig.)
- 1946** **621 .335 (.494)**
 Railway Gazette, No. 5, February 1, p. 119.
New Swiss double-unit electric locomotives. (1 300 words & fig.)
- 1946** **625 .1 (.42)**
 Railway Gazette, No. 5, February 1, p. 121.
The Gloucester-Cheltenham quadrupling. (2 100 words & fig.)
- 1946** **656 .261 (.42)**
 Railway Gazette, No. 6, February 8, p. 147.
London cartage organisation, Southern Railway. (1 000 words.)
- 1946** **625 .232 (.42)**
 Railway Gazette, No. 6, February 8, p. 147.
Modernised restaurant cars on the G. W. R. (500 words & fig.)
- Railway Mechanical Engineer.** (New York.)
- 1940** **621 .392 (.73) & 625 .241 (.73)**
 Railway Mechanical Engineer, May, p. 181.
All-welded flat cars. (600 words & fig.)
- 1940** **621 .133 .3 (.73) & 691 (.73)**
 Railway Mechanical Engineer, May, p. 182.
SCHROEDER (W. C.). — The causes and the prevention of embrittlement in boilers. (3 600 words & fig.)
- 1940** **621 .338 (.73)**
 Railway Mechanical Engineer, May, p. 186.
ANDERSON (H.). — Illinois Central builds three heater cars. (2 000 words & fig.)
- 1940** **621 .132 .5 (.73)**
 Railway Mechanical Engineer, May, p. 187.
Twenty-five improved Northern type 4-8-4 locomotives for C. N. R. (1 500 words & fig.)
- 1940** **621 .138 .5 (.73)**
 Railway Mechanical Engineer, May, p. 199.
A new atlas journal jack. (500 words & fig.)
- 1940** **625 .244 (.71)**
 Railway Mechanical Engineer, June, p. 211.
Overhead icing in C. N. refrigerator cars. (2 500 words & fig.)
- 1940** **621 .132 .5 (.73)**
 Railway Mechanical Engineer, June, p. 216.
Milwaukee buys more 4-8-4 freight power. ((1 500 words & fig.)
- 1940** **621 .134 .1 (.73) & 669**
 Railway Mechanical Engineer, June, p. 219.
GRANT (L. E.) & CROSSETT (J. W.). — Quenched and tempered locomotive forgings. (2 800 words & fig.)

In Spanish.

- Boletin de la Asociacion Internacional Permanente del Congreso Sudamericano de Ferrocarriles.** (Buenos-Aires.)
- 1942** **656 .286 (.8)**
 Boletin de la Asoc. intern. perm. del Congreso Sudamericano de Ferrocarriles, septiembre-octubre, p. 11.
DEL PRIORE (A. R.). — Accidentes al publico las vias ferreas. (3 000 palabras.)
- 1942** **385 .52 (.8)**
 Boletin de la Asoc. intern. perm. del Congreso Sudamericano de Ferrocarriles, noviembre-diciembre, p. 11.
GODERIN (E.). — Produccion y remuneracion. Generalización y modificación de la formula de Rowan. (1 500 palabras.)
- 1942** **385 .(09) (72)**
 Boletin de la Asoc. intern. perm. del Congreso Sudamericano de Ferrocarriles, noviembre-diciembre, p. 35.
NUNEZ BRIAN (J.). — Los transportes ferroviarios del Canada. (1 200 palabras, graficos.)
- 1943** **385 .113 (.8)**
 Boletin de la Asoc. intern. perm. del Congreso Sudamericano de Ferrocarriles, enero-febrero, p. 82.
Explotación de los ferrocarriles de Colombia en 1942 (2 000 palabras & cuadros.)
- 1943** **621 .33 (.49)**
 Boletin de la Asoc. intern. perm. del Congreso Sudamericano de Ferrocarriles, enero-febrero, p. 97.
DUDLER (A.). — La linea de Seebach a Wettingen. Cuna de la electrificación de los Ferrocarriles Federales suizos. (3 000 palabras & fig.)
- 1943** **385 .113 (.8)**
 Boletin de la Asoc. intern. perm. del Congreso Sudamericano de Ferrocarriles, marzo-abril, p. 11.
Resultado de la explotacion de los Ferrocarriles argentinos en el ejercicio 1941-1942. (800 palabras & cuadros)
- 1943** **385 .(09) (72)**
 Boletin de la Asoc. intern. perm. del Congreso Sudamericano de Ferrocarriles, marzo-abril, p. 57.
NUNEZ BRIAN (J.). — La red ferroviaria mexicana (2 000 palabras & cuadros.)
- 1943** **625 .172 (.8)**
 Boletin de la Asoc. intern. perm. del Congreso Sudamericano de Ferrocarriles, mayo-junio, p. 11.
Conservación de la via por el sistema de levante cabrado. (5 000 palabras & fig.)
- 1943** **625 .172 (.8)**
 Boletin de la Asoc. intern. perm. del Congreso Sudamericano de Ferrocarriles, mayo-junio, p. 63.
CARIOLA (J.) & LOPEZ (E.). — Conservación de la via por metodos soufflage y fichage. (2 500 palabras & fig.)

Ferrocarriles y Tranvías. (Madrid.)

1941 **625 .23 (.469)**
 Ferrocarriles y Tranvías, junio, p. 157.
 Memoria relativa al **material** americano adquirido por
 Companhia dos Caminhos do Ferro Portugueses.
 000 palabras & fig.)

1941 **656**
 Ferrocarriles y Tranvías, junio, p. 162.
MARCIA-LÓMAS (J. M.). — Sistemas de **explotación**.
 000 palabras.)

1941 **656 (.460)**
 Ferrocarriles y Tranvías, julio, p. 186; agosto, p. 218.
PEREZ CONESA (Gregorio). — Los **transportes ter-**
restres en la reconstrucción de España. (8 000 palabras
 fig.)

1941 **656 .232**
 Ferrocarriles y Tranvías, julio, p. 195.
BARCELO (J.). — **Costes y precios.** (2 300 palabras.)

1941 **656 .25**
 Ferrocarriles y Tranvías, agosto, p. 226; octubre, p. 289.
CONNOR (A.). — **Senalización ferroviaria.** (8 200
 abras & fig.)

1941 **385 .15 (.460) & 385 .4 (.460)**
 Ferrocarriles y Tranvías, agosto, p. 238.
 Decreto de **organización y administración** de la Red
 cional de los Ferrocarriles Españoles. (3 000 palabras.)

1941 **625 .2 : 625 .62**
 Ferrocarriles y Tranvías, septiembre, p. 254.
FUG (Ad.-M.). — Desarrollo y porvenir del **coche de**
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1941 **621 .132 .1 (.43)**
 Ferrocarriles y Tranvías, septiembre, p. 257.
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 ricipción de los tipos mas destacados. (11 000 palabras
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Revista de Obras Públicas. (Madrid.)

1944 **621 .131 .2**
 ista de Obras Publicas, nº 2745, 1 de enero, p. 13.
ONTIVEROS (F. J.). — Posibilidades de la **locomotora**
vapor. (8 000 palabras & fig.)

1944 **62. (01 & 691**
 ista de Obras Publicas, nº 2746, 1 de febrero, p. 72.
NGULO (A.). — Nomograma para calcular secciones
 lares de **hormigón armado** sometidas a flexion com-
 sta y tensoflexion. (1 000 palabras & fig.)

1944 **625 .42 (.460)**
 ista de Obras Publicas, nº 2747, 1 de marzo, p. 104.
ALZADA (M.). — La nueva línea de Bulevares del
ropolitano de Madrid. Desviació de colectores en la
 za de Colón. (4 000 palabras & fig.)

1944 **621 .33 (.460)**
 Revista de Obras Publicas, nº 2747, 1 de marzo, p. 112;
 nº 2748, 1 de abril, p. 179; nº 2749, 1 de mayo,
 p. 245; 1 de julio, p. 350.
ANGULO (A.) & BADILLO (J.). — La **electrificación**
 Madrid-Avila y Villalba-Segovia. (6 000 palabras & fig.)

1944 **656 (.460)**
 Revista de Obras Publicas, nº 2747, 1 de marzo, p. 118.
PELLICO PEREZ (J. M.). — Transportes por carre-
 tera. **Ordenación-coordinación.** (8 000 palabras.)

1944 **624 .2 & 624 .6**
 Revista de Obras Publicas, nº 2748, 1 de abril, p. 187.
VIADER MUNOZ (A.). — El efecto de la **sobrecarga**
móvil en los arcos empotrados. (1 500 palabras & fig.)

1944 **621 .33**
 Revista de Obras Publicas, nº 2748, 1 de abril, p. 195.
ONTIVEROS (F. J.). — **Electrificación** de transportes
 terrestres. (4 500 palabras.)

In Italian.

Annali dei Lavori pubblici. (Roma.)

1944 **624 .2**
 Annali dei lavori pubblici, gennaio-dicembre, p. 55.
DI BERARDINO (V.). — Nuovi metodi di **calcolo dei**
sistemi iperstatici più comuni. (3 000 parole & fig.)

Giornale del Genio Civile (Roma).

1945 **623 (.45) & 624 (.45)**
 Giornale del Genio Civile, marzo-aprile, p. 119.
CESTELLI GUIDI (C.). — Il **ripristino di un ponte**
danneggiato da operazioni belliche. (2 000 parole & fig.)

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 Giornale del Genio Civile, maggio-giugno, p. 266.
KAMBO (L.). — Sul calcolo dei **ponti rettilinei a**
travi incrociate. (8 000 parole & fig.)

L'Ingegnere. (Milano.)

1942 **624 .63**
 L'Ingegnere, nº 5, 15 maggio, p. 471.
MATTIAZZO (F.). — **Ponti in cemento armato pre-**
compresso. (4 000 parole, 1 tabella & fig.)

1942 **693**
 L'Ingegnere, nº 7, 15 luglio, p. 700.
SESTINI (Quirino). — I **cementi ferrici** e le loro
 applicazioni. (3 500 parole & fig.)

1942 **623**
 L'Ingegnere, nº 8, 15 agosto, p. 803.
MATERNINI (M.). — Alcune **considerazioni sulle**
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1942 **691 & 721 .9**
 L'Ingegnere, nº 8, 15 agosto, p. 814.
SANTARELLA (M. G. Mattiazzo). — Applicazioni
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1943
L'Ingegnere, n° 3, 15 marzo, p. 273.
TURAZZA (G.). — Calcolo generale della **trave Viendeel** a correnti paralleli. (2 500 parole, 3 tabelle & fig.)

1943
L'Ingegnere, n° 5, 15 maggio, p. 537.
ZANELLI (A.). — L'impianto di **posta pneumatica** « a stazioni intermedie di linea » nel **deposito locomotori** di Napoli Smistamento delle F. S. (5 000 parole & fig.)

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L'Ingegnere, n° 6, 15 giugno, p. 677.
REPOSSI (G.). — Trasmissione ad ingranaggi per **motori di trazione** di tipo tranviario. (3 000 parole & fig.)

1943
L'Ingegnere, n° 6, 15 giugno, p. 689.
ROSATI (L.). — Prove su pali di **fondazione**. (2 200 parole & fig.)

Rivista tecnica delle Ferrovie italiane. (Roma.)

1940
Rivista tecnica delle ferrovie ital., 15 ottobre, p. 131.
CIOCIA (D.). — La **riparazione delle locomotive elettriche** e l'attrezzatura dei Depositi. (6 000 parole, 3 tabelle & fig.)

1940
Rivista tecnica delle ferrovie ital., 15 ottobre, p. 154.
GIORGIO de GIORGI. — Alcuni esempi di importanti **modifiche del traccia di binari** eseguite col metodo delle frecce. (2 100 parole & fig.)

1940
Rivista tecnica delle ferrovie ital., 15 ottobre, p. 159.
AZZARELLO (E.). — Uno studio chimico sui **petardi da segnalamento**. La determinazione del clorato potassico in uso nelle Ferrovie dello Stato. (1 500 parole & 1 tabella.)

1940
Rivista tecnica delle ferrovie ital., 15 novembre, p. 169.
SACCOMANI (L.) & DEL ZANNA (A.). — Una grande officina italiana per **riparazione locomotive elettriche**. (12 000 parole, tabelle & fig.)

1940
Rivista tecnica delle ferrovie ital., 15 novembre, p. 205.
DI MAJO (F.). — **Avviamento e cambio di velocità nelle automotrici**. Metodo grafico per la determinazione del perditempo d'avviamento e per la ricerca della più conveniente serie di rapporti in un cambio ad ingranaggi. (3 600 parole, tabelle & fig.)

1940
Rivista tecnica delle ferrovie ital., 15 dicembre, p. 237.
MARTINELLI (M.). — L'impianto di **condizionamento dell'aria negli elettrotreni** delle Ferrovie dello Stato (2a serie — 207 : 218) e le ultime migliori introdotte per la sua regolazione. (2 200 parole & fig.)

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Rivista tecnica delle ferrovie ital., 15 dicembre, p. 2.
SELLERI (G.). — Metodo tacheometrico per misurare la **tensione meccanica dei conduttori** delle linee elettriche (2 400 parole & fig.)

1940

Rivista tecnica delle ferrovie ital., 15 dicembre, p. 2.
BENEDETTI (E.). — La **ferrovia Gibuti-Addis Abeba** (10 500 parole, 11 tabelle & fig.)

In Dutch.

Spoor- en Tramwegen. (Utrecht.)

1940

Spoor- en Tramwegen, Nr. 26, 21 December, p. 517.
VAN SETTEN (D.). — De **Spoorwegen** in Spanje (3 000 woorden & 1 kaart.)

1940

Spoor- en Tramwegen, Nr. 26, 21 December, p. 529.
DE VRIES (S. W.). — Het nut van coördinatentekeningen bij het **uitzetten van sporen en wissels**. (1 400 woorden & fig.)

1941

Spoor- en Tramwegen, Nr. 1, 4 Januari, p. 2.
ERKENS (P. J.). — **Invoer per spoor**. (3 600 woorden & fig.)

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Spoor- en Tramwegen, Nr. 1, 4 Januari, p. 9.
Een eeuw **railverkeer** in Italië. (1 400 woorden & fig.)

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Spoor- en Tramwegen, Nr. 1, 4 Januari, p. 10.
De **Staatsspoorweg** in Alaska. (2 800 woorden & 1 kaart.)

1941

Spoor- en Tramwegen, Nr. 2, 18 Januari, p. 21.
LABRIJN (P.). — **Vuurloze stoomlocomotieven**. (2 400 woorden, 4 tabellen & fig.)

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VAN RAVESTEYN (S.). — De **verbouwing van de spoorwegen** in Utrecht C. S. (1 000 woorden & fig.)

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Spoor- en Tramwegen, Nr. 3, 1 Februari, p. 41.
JACOPS (A.). — De **ventilatie van den Tunnel Noord-Zuidverbinding te Brussel**. (3 000 woorden & fig.)

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Spoor- en Tramwegen, Nr. 3, 1 Februari, p. 46.
VAN DER VLIS (J. H.). — **Gebreken in de spoorwegen** (2 300 woorden.)

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Spoor- en Tramwegen, Nr. 3, 1 Februari, p. 48.
VAN SETTEN (D.). — De **ontwikkeling van de spoorwegverkeer** in Griekenland. (2 500 woorden & fig.)

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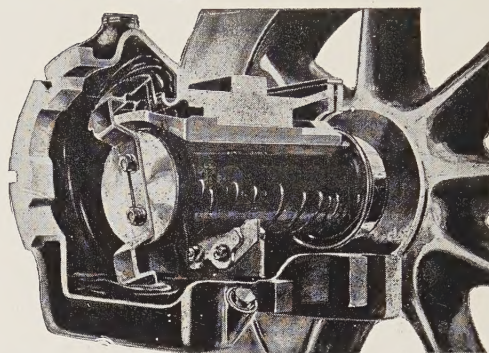
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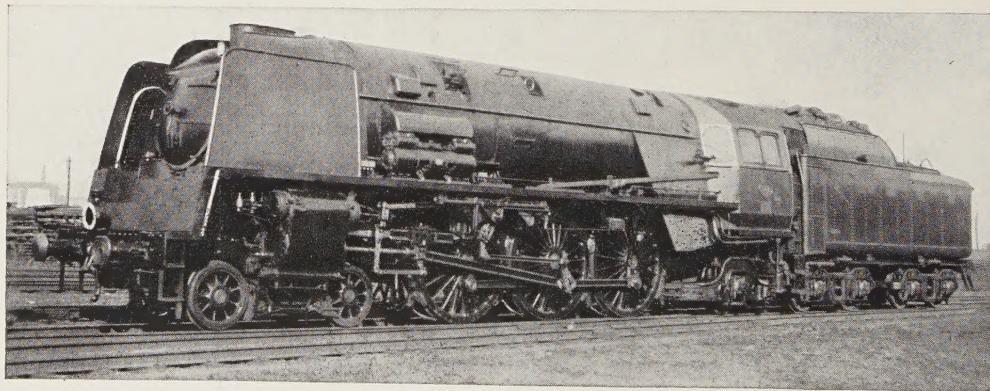
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